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Species abundance patterns and productivity of birds using grassed waterways in Iowa rowcrop fields

by

Georgia Gaye Bryan

A Thesis Submitted to the

Graduate Faculty in Partial Fulfillment of the

Requirements for the Degree of

MASTER OF SCIENCE

Department: Animal Ecology

Major: Wildlife Biology

Signatures have been redacted for privacy

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GENERAL INTRODUCTION

Technological advances have led to increasingly intensive agricultural practices in the midwestern United States. With intensive agricuture came increased use of machinery, single cropping systems, and agricultural chemicals. These advances allowed a farmer to till more land than in the past and, subsequently, farm sizes increased. In Iowa, the average farm size doubled from 1940 to 1987 (U.S.D.A. 1988). Intensive agriculture, coupled with this increase in farm size, led to the destruction of much of the native grassland and wetland habitat in the midwest. Nearly 100% of the wetlands and presettlement prairie have been lost in Iowa alone (Bishop 1981, Smith 1981). In light of the loss of native habitat, the importance of areas that provided a "substitute" habitat for some species has heightened. These substitute areas include: fencerows, roadsides, pastures, cropfields, and grassed waterways. Increasing farm size, however, has begun to encroach on these areas as well, which is exemplified by the accelerated removal of fencerows (Vance 1976).

In recent years, the need for management recommendations for wildlife in agricultural areas has received considerable attention (e.g., Best 1983, Castrale 1985, O.T.A. 1985, Basore et al. 1986, Ryan 1985, Frawley 1989). Grass waterways have been promoted for their benefits to wildlife, but to date, use of grassed waterways by wildlife has not been documented in the literature. My study will not only answer questions concerning wildlife use of grassed waterways, but also will provide some much needed recommendations concerning management and establishment of grassed waterways for landowners and others interested in enhancing these areas for wildlife.

Explanation of Thesis Format

The alternate thesis format was used to prepare this thesis. In accordance to the guidelines provided for this format, the sections are written in the accepted style for submission for publication in scientific journals. Section I deals with species richness and bird abundance patterns in grassed waterways in Iowa rowcrop fields. Section II reports productivity of birds in grassed waterways. Data acquisition, statistical analyses, and the preparation of the text for both sections were the responsibility of the candidate; however, guidance and editorial advice were supplied by Dr. Louis B. Best.

SECTION I. BIRD ABUNDANCE AND SPECIES RICHNESS PATTERNS IN GRASSED WATERWAYS IN IOWA ROWCROP FIELDS

ABSTRACT

Grassed waterways have been used for decades to prevent soil erosion in agricultural cropland, but their benefits to wildlife had not been evaluated previously. We documented bird species composition and relative abundance during the breeding season in 44 waterways in central Iowa. The waterways were planted predominately to smooth brome and were in cornfields and soybean fields. Forty-eight bird species were observed in waterways, compared with only 14 in the surrounding crop field. Red-winged blackbirds (Agelaius phoeniceus), dickcissels (Spiza americana), barn swallows (Hirundo rustica), western meadowlarks (Sturnella neglecta), brown-headed cowbirds (Molothrus ater), grasshopper sparrows (Ammodramus savannarum) and song sparrows (Melospiza melodia) were the most abundant bird species in the grassed waterways. Total bird abundance in the grassed waterways averaged 2,198 birds/100 ha compared to 682 birds/100 ha in crop fields.

Several waterway characteristics (e.g., grass and forb coverage, vegetation height and density) were significantly ($P \leq 0.05$) related to bird species richness and abundance in waterways. Bird use of waterways also was affected by the proximity of the waterways to diverted areas and by certain agricultural disturbances. In fields where crop rows ran perpendicular to the waterways, the increased farm vehicle disturbance in the waterways discouraged bird use of the waterways. Mowing, which drastically altered the structure of the habitat, greatly influenced bird use of the waterways; some bird species preferred mowed waterways, others preferred unmowed. Temporal patterns in bird abundance were attributed primarily to aspects of the waterways and surrounding cropland, such as crop and vegetation height, that changed over time. Bird abundance was greater in the segment of the waterways adjoining another habitat type than in segments farther from the edge habitat. Because most (53%) of the species were at peak abundance in the waterways during 4 - 22 July, waterways should not be mowed until the end of August or early September.

INTRODUCTION

Grassed waterways have been promoted by the U.S. Soil Conservation Service to prevent soil erosion since 1947 (Temple 1983). They are "natural or constructed channels that have been shaped to transport water at a nonerosive velocity from fields, diversions, terraces, and roadside ditches." Grass species planted in the channel are determined by geographic location and erosion potential. These species are predominantly cool season grasses because of their quick establishment and even, dense growth (U.S.S.C.S. 1975).

From the outset, waterways have been promoted for their benefits to wildlife, particularly ring-necked pheasants (for scientific names of bird species see Table 4a) and other upland game birds. Studies have been conducted on some linear habitats associated with agricultural cropland (e.g., fencerows: Allen 1941, Best 1983, Shalaway 1985; shelterbelts: Yahner 1982, 1983a,b), but, to date, use of grassed waterways by wildlife has not been documented. Basore et al. (1986) included grassed waterways in an assessment of bird nesting densities and nesting success, but the waterways were not distinguished from other types of strip cover. High densities of nesting birds have been found in narrow habitats comparable to grassed waterways (e.g., Shalaway 1985, Basore et al. 1986). Therefore, similar densities also may be found in waterways, particularly for grassland species.

The need for research on waterways became even more important with the passage of the 1985 Farm Bill. The Conservation Compliance Provision requires landowners to implement a conservation plan if they continue to farm annually tilled crops on highly erodible land. This is expected to increase conservation tillage, terracing, and the number of grassed waterways (U.S.D.A. 1986). In Iowa there are 99 counties, and in Marshall County alone, over 50 waterways were constructed from 1983-1987 (D. Baloun, U.S.S.C.S., pers. comm.). In light of the high rate of fencerow removal (Vance 1976), the increase in the number of grassed waterways will assume even greater importance as wildlife habitat in agricultural areas. Therefore, management guidelines are needed for the establishment and maintenance of the growing number of grassed waterways to improve their value for wildlife.

The objectives of our study were: 1) to ascertain which avian species use grassed waterways during the breeding season and to what extent, 2) to assess the influence of various waterway characteristics on bird use, and 3) to develop waterway management strategies for landowners and others interested in enhancing these areas for wildlife.

STUDY AREA

The waterways chosen for study were in Story and Marshall counties in central Iowa. This area is nearly level to gently rolling. The average daily maximum temperature in summer is 30^{o} C, and the mean midday relative humidity is 60%. Total annual rainfall averages 86 cm, with 61 cm of this falling between April and September (Oelmann 1981). Waterways were selected in cornfields and soybean fields because these constitute 76% of the cropland in Iowa (U.S.D.A. 1988). Also, fields with reduced tillage (i.e., no fall plowing) were chosen to avoid extremes in tillage practices that might influence birds' use of the waterways (Basore et al. 1986). Reduced tillage is the prevailing practice in Story and Marshall counties.

A random sample of 60 waterways in Story and Marshall counties, that met U.S. Soil Conservation Service specifications (U.S.S.C.S. 1975), was characterized on the basis of plant species seeded in the waterway, the waterway configuration (linear vs. dendritic), and whether or not the waterway was connected to other strip cover. According to specifications, waterways are trapezoidal or parabolic in cross section, vary in length, and range from 9 to 30 m wide. Ninety percent of the sampled waterways were planted to smooth brome (Bromus inermis) or predominately smooth brome mixes, including orchard grass (Dactylis glomerata), reed canary grass (Phlarais arundinacea), timothy (Phleum pratense), and switchgrass (Panicum virgatum). Sixty-three percent of the waterways were linear or had relatively few smaller, divergent channels, and 37% were dendritic. Ninety-five percent of the waterways were connected on one or both ends to roadside ditches, fencerows, or other drainage areas; the remainder (5%) were unconnected, ending in the fields.

METHODS AND MATERIALS

Study Site Selection

The 44 waterways selected for study (1987: $\underline{n} = 24$, 1988: $\underline{n} = 20$) represented the predominant waterway characteristics described previously, i.e., they were planted to smooth brome, straight, and connected to strip cover. The waterways selected varied in width and length.

To facilitate comparing variables measured within each waterway, the 24 waterways were chosen for study in 1987 according to 6 classes based on length and width. To determine these classes, the initial random sample of 60 waterways described in STUDY AREA was divided into groups, with an effort made to balance the number of waterways within each class and the range of each class. The width classes were 9.0-11.5 m (28% of the total random sample), 12.0-14.5 m (46%), and 15.0-30 m (26%); and the length classes were 60-304 m (27%), 305-609 m (28%), and >609 m (45%). Because certain widths and lengths were more prevelant than others, the most common width class was used when comparing among length classes and vice versa. Thus waterways chosen for the 3 width classes were all from the >609 m length class (i.e., length was held constant). Likewise, waterways selected for the 3 length classes were all from the 12.0-14.5 m width class. Twenty of the waterways were in fields with corn residue; the remaining 4 were in fields with soybean residue.

In 1988, we selected 20 other waterways based on the habitat types adjoining the ends of the waterways. Five habitat types were chosen for study, with 4 waterways in each: farmsteads, creeks, woodlots, pastures, and herbaceous fencerows. To increase sample sizes, after preliminary analysis, the habitat types were consolidated into 2 groups distinguished by presence or absence of trees/shrubs (i.e., woodlots, farmsteads, and creeks vs. fencerows with herbaceous vegetation and pastures). The presence of woody vegetation greatly influences avian species composition and abundance in agricultural areas (Best 1983). The 20 waterways were chosen in fields that did not have diverted areas (areas taken out of crop production and planted to some form of cover) adjacent to or near the waterways.

Bird Census

Two census methods were used to estimate relative bird abundance. The first was a modified point count census (Dawson 1981). The modification was necessary because of inherent problems in studying birds within a linear habitat in open country. The waterways were divided along their lengths into segments 100 m long, which were marked with surveying flags. For each segment, a corresponding observation point was located in the field 25 m from the waterway to minimize disturbing bird activity. When the observer approached a waterway, any birds flushed from the waterway were recorded. Then, in sequence, birds were observed within each segment for 5 min. Observations were recorded on maps of the study site, and only those birds using the waterway or its immediate edge were noted. Although flyovers were excluded, birds that forage in flight, such as raptors and barn swallows, were counted if they were foraging over the waterway. As the season progressed and the crop plants grew taller, this method became infeasible. Consequently, a second census procedure, which could be continued later in the season, was used to supplement the point counts. This entailed slowly walking along the length of 1 side of each waterway and recording the birds observed. For both census procedures, each waterway was censused alternately by 2 observers, thus reducing observer bias. Waterways were censused weekly from early May through early August during 1987 and 1988.

For comparison, 22 field plots were censused concurrently with the waterway plots. Fields for these plots were randomly selected from the 44 fields containing waterway study sites. Half of the fields were selected each year. The field plots were 15 x 100 m, which was the average size of 1 waterway segment. These plots were established in the middle of fields to reduce edge effects (see Best et al. 1990) and any influence of the waterway. Plots were at least 300 m from waterways, fencerows, and roadsides. These plots were censused using the methods described previously.

Vegetation Measurements

A subsample of the waterways (1987: $\underline{n}$ = 12, 1988: $\underline{n}$ =10) was selected for vegetation measurements by randomly choosing 2 waterways from each class of waterways. In addition, vegetation composition data were collected from 19 waterways in 1988. A stratified random sampling design was used to measure vegetation at waterways. One strip, 15 m wide, was delineated in the crop field on each side of a waterway, and the waterway constituted a third strip. The strips were divided into segments 100 m long, and one sample site was located randomly within each segment. At least 5 samples were taken in each waterway. If the waterway had fewer than 5 segments, more than 1 sample was taken in each segment.

Four variables were measured at each waterway: waterway residue cover, and vegetation height, density, and composition. Crop residue cover was sampled in the crop field strips in April by the bead string technique (Sloneker and Moldenhauer 1977). A 10-ft (3.1 m) long string with beads (marks) at 1-ft (15.3 cm) intervals was placed diagonal to the crop rows, and the number of beads that touched residue was recorded (Basore et al. 1986). Height of the field crops and height and density of the herbaceous vegetation in waterways were recorded twice a month. Vegetation density was measured with a density board (Gysel and Lyon 1980),15 cm wide and 180 cm tall, graduated at 10-cm intervals. At each sampling point, the board was read from the 4 cardinal directions at a distance of 3 m and a height of 1

m. The proportion of each interval obscured by vegetation was categorized as 0-20, 21-40, 41-60, 61-80, or 81-100% and recorded as 1-5, respectively. Density was calculated by averaging the measurements from the 4 cardinal directions at each interval and then summing over all intervals (Basore et al. 1986). In June, the peak nesting period, the composition of herbaceous vegetation in the waterways was determined by estimating the percent canopy coverage of plant species within a 1 m^2 quadrat. Individual coverages within each quadrat were estimated on a non-overlapping basis, thus total coverage summed to 100%. Only species with coverages of 5% or more were recorded. Herbaceous vegetation composition also was characterized by growth form (i.e., grasses, forbs, and shrubs). Coverage of residue and bare ground also was included in composition measurements. Because trees were generally restricted to adjoining fencerows and were found growing in only 1 waterway sampled, they were not included as a growth form.

Statistical Analysis

Differences in bird abundance and species richness among waterways were evaluated by using analysis of variance (ANOVA) procedures. The influence of waterway width, length, segment, and end type on bird abundance and species richness were determined by using the General Linear Models (GLM) procedure (SAS Inst. Inc. 1985). Temporal changes in bird species richness and abundance were evaluated according to 4 periods (15 May-1 June, 2 June-18 June, 19 June-3 July, and 4 July-22 July), and the periods were regarded as a repeated measure (Cochran and Cox 1957: 293-316). When comparing means from only 2 groups of observations, student's t-tests were used. Bird abundance and species richness were averaged over time for comparisons between years and between waterways and field plots. Also, when variances between 2 groups were unequal, Satterthwaite's approximation was used to compute the "effective degrees of freedom" (Steel and Torrie 1980: 106). Other tests used are described in the Results and Discussion where appropriate. Statistical significance was set at $\underline{P} \leq 0.05$.

RESULTS AND DISCUSSION

Habitat Characteristics

Vegetation characteristics in grassed waterways differed between 1987 and 1988, primarily because of the drought in 1988. Rainfall was below normal from April through July in 1988, before increasing to average levels in August (Table 1). The height and density of herbaceous vegetation in waterways were greater in 1987 than in 1988 (Table 2). This was most evident by evaluating differences between years for each approximately 2-week interval, because averaging over the entire study period masked drought effects that were present later in the growing season. We compared herbaceous vegetation only in unmowed waterways since vegetation height in mowed waterways was determined largely by mowing practices. Vegetation height in unmowed waterways differed between years during 4 July - 22 July ($t = 2.25$, 7 df, $P = 0.05$), approached significance during 2 June - 18 June ($t = 2.07$, 7 df, $P = 0.09$), but was not significantly different 19 June - 3 July ($P = 0.56$). Vegetation density in unmowed waterways differed between years only during 2 June - 18 June ($t = 2.44$, 5 df, $P = 0.05$), but did not differ significantly 19 June - 3 July or 4 July - 22 July ($P = 0.36$ and $P = 0.28$, respectively).

In contrast to the herbaceous vegetation in waterways, the average height of corn and soybeans and the average coverage of corn and soybean residue were not significantly different between years ($P = 0.38$ and $P = 0.54$, respectively). The percent coverage of residue was typical of reduced tillage systems (Best 1986) in 1987 (corn residue: $\bar{x} = 56\%$, SE = 17.3, $n = 5$; soybean residue: $\bar{x} = 30\%$, SE = 11.1, $n = 5$) and 1988 (corn residue: $\bar{x} = 61\%$, SE = 11.8, $n = 6$; soybean residue: $\bar{x} = 38\%$, SE = 14.2, $n = 4$).

Grass was the most common vegetation growth form in the waterways, being at least 3 times more abundant than forbs, the second most common growth form (Table 3).

Table 1. Climatological information for Story County, Iowa April - August 1987-88[a] and averages from 1951-73[b] (normal)

	Temperature (daily maximum °C)			Total precipitation (cm)		
Month	1987	1988	Normal	1987	1988	Normal
April	20	18	16	5.5	4.4	8.4
May	27	28	22	9.2	4.5	11.4
June	30	32	28	7.7	5.3	11.8
July	31	32	30	12.1	8.6	11.0
August	27	32	28	32.0	15.4	9.6

[a]Source: Department of Climatology and Meterorology, Iowa State University, Ames, Iowa.
[b]Source: Oelmann (1981).

Table 2. Vegetation characteristics of grassed waterways and surrounding cropfields at 2-week intervals from 15 May through 22 July, 1987-88 in Story and Marshall counties, Iowa

		1987							
		15 May - 1 June		2 June - 18 June		19 June - 3 July		4 July - 22 July	
	n	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Vegetation height (cm)									
Unmowed [a]	8	92	6	100	7	96	31	115	38
Mowed [b]	4	54	7	67	3	65	33	26	6
Vegetation density [c]									
Unmowed [a]	8	49	14	46	23	45	14	46	18
Mowed [b]	4	33	6	37	9	30	9	25	3
Corn height (cm)	6	0	0	59	39	171	45	209	10
Soybean height (cm)	6	0	0	25	5	49	11	84	9

[a]Includes only grassed waterways that were not mowed, burned, or grazed.
[b]Includes only grassed waterways that were annually mowed.
[c]Calculated by summing the individual interval readings from the density board.

	1988							
	15 May - 1 June		2 June - 18 June		19 June - 3 July		4 July - 22 July	
n	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
4	--	--	68	15	83	32	76	16
6	--	--	69	24	23	8	34	13
4	28	4	33	5	38	7	35	13
6	--	--	30	4	22	2	23	4
5	21	4	58	44	138	59	234	55
5	16	5	31	10	42	10	56	25

Table 3. Canopy coverage (%) of growth forms and major [a] plant species[b] in grassed waterways in Story and Marshall counties, Iowa during June, 1987-88

	1987 (n = 12)		1988 (n = 19)		
	$\bar{x}$	SE	$\bar{x}$	SE	$P > t$[c]
Grasses	66	23	60	26	0.59
Orchard grass (*Dactylis glomerata*)	3	9	14	23	< 0.01
Foxtail barley (*Hordeum jubatum*)	3	6	1	3	0.30
Western wheatgrass (*Agropyron smithii*)	1	1	5	12	0.12
Giant foxtail (*Setaria faberii*)	17	26	1	4	0.05
Orange foxtail (*Setaria glauca*)	2	7	1	3	0.57
Timothy (*Phleum pratense*)	6	8	1	3	0.10
Reed canary grass (*Phalaris arundinacea*)	10	27	3	11	0.38
Switchgrass (*Panicum virgatum*)	2	6	1	5	0.79
Smooth brome (*Bromus inermis*)	34	25	36	27	0.77

Forbs [d]	20	18	20	25	0.92
Common milkweed (Asclepias syriaca)	1	1	1	1	0.24
Sweet clover (Melilotus spp.)	1	2	4	13	0.43
Alsike (Trifolium hybridum)	3	8	1	1	0.35
Alfalfa (Medicago sativa)	4	9	7	12	0.55
Bull thistle (Cirsium vulgare)	1	1	1	1	0.74
Canada thistle (Cirsium arvense)	1	1	2	5	0.34
Commmon ragweed (Ambrosia artemisiifolia)	2	6	1	1	0.23
Giant ragweed (Ambrosia trifida)	4	8	1	2	0.11
Shrubs	1	1	0	0	0.34
Bare ground	13	25	3	6	0.20
Residue	1	2	16	13	< 0.01

[a]Major = plant species whose coverage was $\geq$ 1 % both years.

[b]Source of scientific and vernacular names: Gleason and Cronquist (1963), Hitchcock (1971).

[c]Student's t-test comparing canopy coverage (%) between years.

[d]Additional forbs (mean $\pm$ SE) that were major species only during 1 year: 1987: stinging nettle (Urtica dioica) 1 $\pm$ 3, pinkweed (Polygonum pensylvanicum) 2 $\pm$ 7, plantain (Plantago Rugelii) 1 $\pm$ 4, tall coneflower (Rudbeckia laciniata) 1 $\pm$ 4, daisy fleabane (Erigeron philadelphicus) 1 $\pm$ 4, and velvet-leaf (Abutilon Theophrasti) 1 $\pm$ 3; 1988: red clover (Trifolium pratense) 1 $\pm$ 3.

Typically, waterways are planted to grass mixes, and any forbs present are usually invading weeds. Although waterways are sometimes planted with a legume in the grass mixture, this practice is generally discouraged because legumes are short-lived, leaving bare spots exposed to erosion (U.S.D.A. 1960). Shrubs were scarce in the waterways (Table 3).

The percent coverage of grass, forbs and shrubs did not differ significantly between years (Table 3). In contrast, residue in waterways increased from 1987 to 1988, which we attributed to the drought drying out some of the grass, which was then categorized as residue. The amount of bare ground also differed between years.

Nine grass species were recorded in waterways (Table 3). Smooth brome was the most abundant species, which is consistent with our waterway selection criteria. Orchard grass, reed canary grass, and giant foxtail were the next most common grass species. The prevelance of smooth brome and reed canary grass in the waterways reflects U.S.D.A. (1960) planting recommendations. Smooth brome is one of the most commonly used grass species in waterways in many regions of the United States, and reed canary grass is often recommended for use in extremely wet sites. Giant foxtail is a common weed pest in the cornbelt (U.S.D.A. 1985), and it often invaded the waterways.

Twenty-six forb species were found in our waterways (Table 3). Alfalfa was the most abundant forb species, followed by sweet clover, alsike, and common and giant ragweed. The lower abundances of the major forb species compared to the major grass species is consistent with planting recommendations; none of the legumes mentioned in Table 3 are commonly planted in waterways (U.S.D.A. 1960). Because most forb species listed in Table 3 are regarded as weed pests and are usually controlled in crop fields, they were uncommon in waterways (U.S.D.A. 1985). The only shrub species recorded was common elderberry (Sambucus canadensis). This woody plant had invaded 1 waterway that was not mowed annually.

The coverages of some grass species differed considerably between years, whereas coverages of others were similar (Table 3). This was probably due to differences among species in their responses to drought conditions and to differences in waterway plantings. For example, smooth brome coverage was similar in 1987 and 1988, whereas the coverages of giant foxtail, timothy, and reed canary grass declined measureably. The difference in the coverage of reed canary grass between years may have been due to the species' affinity for wet areas, thereby making it less drought resistant (Hitchcock 1971). The greater coverage of orchard grass and western wheatgrass in 1988 vs. 1987 was most likely due to differences in the grass mixes originally planted in the different sets of waterways studied each year. The difference between years in canopy coverage also varied among forb species; some species seemed to decreased, whereas others increased (Table 3).

Bird Species Composition

Forty-eight bird species were observed in waterways, compared with only 14 in the surrounding crop field. The number of species recorded in waterways vs. field plots differed both years (1987: $t = 14.67$, 29 df, $P < 0.01$; 1988: $t = 10.13$, 26 df, $P < 0.01$). The most abundant bird species using waterways were the red-winged blackbird, dickcissel, barn swallow, grasshopper sparrow, brown-headed cowbird, song sparrow, and western meadowlark (Table 4a). In cropfields, the primary species recorded were red-winged blackbirds, vesper sparrows, brown-headed cowbirds, and dickcissels (Table 4b). No species was found exclusively in the crop fields. Waterways provide suitable habitat for a greater diversity of species than the surrounding crop field, given that 3 times more species were observed in the grassed waterways in our study than in the field plots.

No difference was found between years in the mean number of species recorded per waterway ($P = 0.18$). In 1987, an average of 7 species (range 4 - 12) was observed per

Table 4a. Number of birds observed/100 ha using grassed waterways from 15 May through 31 July 1987-88 in central Iowa

	Waterways				
	1987 ($\underline{n}$ = 24)		1988 ($\underline{n}$ = 20)		
Species	$\bar{x}$	SE	$\bar{x}$	SE	$\underline{P} > \underline{t}$[a]
Red-tailed hawk (Buteo jamaicensis)	2	16	1	6	0.46
Northern bobwhite (Colinus virginianus)	0	0	3	18	0.25
Ring-necked pheasant (Phasianus colchicus)*[b]	26	50	47	114	0.19
Gray partridge (Perdix perdix)	6	43	5	27	0.88
Killdeer (Charadrius vociferus)	3	20	34	115	0.05
Upland sandpiper (Bartramia longicauda)	6	42	3	25	0.63
Mourning dove (Zenaida macroura)	8	44	19	93	0.37
Great horned owl (Bubo virginianus)	0	0	6	47	0.32
Eastern kingbird (Tyrannus tyrannus)	0	0	12	50	0.08
Horned lark (Eremophila alpestris)	10	40	91	236	0.01
Tree swallow (Iridoprocne bicolor)	3	21	18	84	0.18
Barn swallow (Hirundo rustica)	80	141	325	826	0.03
Cliff swallow (Petrochelidon pyrrhonota)	14	50	0	0	0.82
American crow (Corvus brachyrhynchos)	1	5	7	52	0.37
Black-capped chickadee (Parus atricapillus)	0	0	2	13	0.32
Sedge wren (Cistothorus platensis)*	2	14	0	0	0.16
Brown thrasher (Toxostoma rufum)	5	25	10	41	0.42
American robin (Turdus migratorius)	14	41	57	134	0.02
Wood thrush (Hylocichla mustelina)	1	5	0	0	0.32
European starling (Sturnus vulgaris)	0	0	45	241	0.15
Common yellowthroat (Geothlypis trichas)*	75	124	51	208	0.42
House sparrow (Passer domesticus)	7	35	41	143	0.07
Bobolink (Dolichonyx oryzivorus)	10	34	3	18	0.19
Eastern meadowlark (Sturnella magna)	4	21	0	0	0.16
Western meadowlark (Sturnella neglecta)*	192	195	115	165	0.02
Red-winged blackbird (Agelaius phoeniceus)*	669	533	356	434	< 0.01
Northern Oriole (Icterus galbula)	0	0	3	21	0.32
Common Grackle (Quiscalus quiscula)	2	15	92	412	0.10
Brown-headed cowbird (Molothrus ater)	136	232	98	163	0.27
Northern cardinal (Cardinalis cardinalis)	0	0	3	26	0.32
Rose-breasted grosbeak (Pheucticus ludovicianus)	0	0	2	13	0.32
Indigo bunting (Passerina cyanea)	6	39	26	92	0.13
Dickcissel (Spiza americana)*	390	394	333	387	0.40
American goldfinch (Carduelis tristis)*	39	132	10	44	0.08
Savannah sparrow (Passerculus sandwichensis)	24	90	5	31	0.09
Grasshopper sparrow (Ammodramus savannarum)*	150	250	61	131	0.01
Vesper sparrow (Pooecetes gramineus)*	91	176	161	249	0.07
Field sparrow (Spizella pusilla)*	4	21	0	0	0.09
Song sparrow (Melospiza melodia)*	158	197	32	98	< 0.01
Total[c]	2238	950	2158	1288	0.65

[a]Student's t-test comparing relative abundance between years.

[b]* = Species observed nesting in the waterways.

[c]Total includes some unidentified birds.

Table 4b. Number of birds observed/100 ha using crop fields from 15 May through 31 July 1987-88 in central Iowa

	Field plots				
	1987 ($\underline{n}$ = 12)		1988 ($\underline{n}$ = 10)		
Species	$\bar{x}$	SE	$\bar{x}$	SE	$\underline{P} > \underline{t}$[a]
Killdeer	11	65	46	163	0.34
Horned lark	8	43	15	75	0.66
Barn swallow	27	86	61	139	0.29
American robin	30	135	0	0	0.21
Common yellowthroat	23	90	15	75	0.74
House sparrow	0	0	15	75	0.33
Western meadowlark	68	172	30	149	0.39
Red-winged blackbird	106	197	319	868	0.25
Common grackle	11	65	61	139	0.12
Brown-headed cowbird	57	229	61	176	0.95
Indigo bunting	23	90	15	75	0.74
Dickcissel	85	208	30	103	0.22
Vesper sparrow	110	212	15	75	0.02
Chipping sparrow	23	129	0	0	0.33
Total [b]	680	681	683	963	0.99

[a]Student's t-test comparing relative abundance between years.

[b]Total includes some unidentified birds.

waterway, and in 1988, 6 species (range 2 - 9). There was a difference between years in the number of species observed per field plot (t = 2.20, 18 df, P = 0.04). Mean values for 1987 and 1988 were 2 (range 1 - 3) and 1 (range 0 - 2) species, respectively.

The total number of species observed in the waterways was similar to that recorded for native grasslands in Alberta, Canada, by using a roadside count census procedure (Owens and Myers 1973), but was 2 to 5 times greater than that reported by others for grassland and hay fields (Graber and Graber 1963; Wiens 1969, 1973; Skinner 1974). These latter studies were conducted in large blocks of similar habitat, rather than in narrow, linear habitats like waterways and roadsides where birds may become concentrated. Eleven species were found nesting in our waterways (Table 4a), which is similar to the number reported for grasslands (Wiens 1973, Blankespoor 1980).

The mean number of species observed in our waterways was more similar to the number found in fencerows with scattered trees and shrubs than in strictly herbaceous fencerows, although the latter have vegetation structure more similar to waterways (Best 1983). This suggests that some aspect(s) of the herbaceous waterway habitat make it as attractive to birds as the enhanced vegetation structure found in fencerows with trees and shrubs.

Best et al. (1990) observed a total of 20 bird species using the centers of cornfields in Iowa and 18 in Illinois. This is greater than the total number of species recorded in the crop fields in our study (Table 4b). Graber and Graber (1963) found a greater number of bird species in cornfields than in soybean fields. Because our study involved both cornfields and soybean fields, the combined species richness would be expected to be less than that found by Best et al., who only evaluated cornfields. Also, Best et al. censused a larger area than our study, which would increase the likelihood of observing rare species.

As described in the Methods, we used a modified point count census to determine the total birds observed/100 ha (Table 4a), and a transect method to assess changes in bird numbers over time. Nine of the 48 species observed in waterways were recorded only by the transect method and were not included in Table 4a. These included greater yellowlegs (Tringa melanoleuca), rock dove (Columba livia), red-headed woodpecker (Melanerpes erythrocephalus), hairy woodpecker (Picoides villosus), downy woodpecker (P. pubescens), blue jay (Cyanocitta cristata), gray catbird (Dumetella cardinensis), chipping sparrow, and American kestrel (Falco sparverius).

Bird Abundance

Total bird abundance in grassed waterways and in field plots did not differ significantly between years, but total bird abundance in waterways was 3 times that in field plots (1987: $t = 8.67$, 29 df, $P < 0.01$; 1988: $t = 2.13$, 19 df, $P = 0.04$). This demonstrates that waterways are more preferred habitat than the surrounding crop fields for most species.

Total bird abundance in the waterways was similar to that reported by Graber and Graber (1963) for mixed hayfields, but about twice what they found for fallow fields and ungrazed grasslands. Most other reports for similar habitats give abundances of only the breeding birds and not total bird abundances (i.e., breeding and non-breeding birds). If only the 14 species found nesting in the waterways are considered, the average total abundance of breeding birds in the waterways was 1,481 birds/100 ha. This is greater than the breeding bird abundances recorded for native grasslands and for agricultural fields with grasses and forbs (Dambach and Good 1940, Owens and Myres 1973, Harrison 1974, Frawley 1989). Abundances of the major bird species were typically greater in the waterways than in other grassland habitats (Dambach and Good 1940; Stewart 1953; Smith 1963; Zimmerman 1971; Wiens 1973; Albers 1978; Whitmore 1979; Janes 1983; Rodenhouse and Best 1983; Besser 1985; Applegate and Willms 1987; Frawley 1989; Blankespoor, Augustana Coll., unpubl. data). Again these differences may reflect the concentration of birds in the smaller, waterway habitat because other larger areas of similar habitat are lacking due to intensive agriculture.

Although total bird abundance in waterways did not differ significantly between years, the abundance of some individual species did. Killdeer, horned lark, and American robin numbers increased significantly from 1987 to 1988, whereas western meadowlarks, red-winged blackbirds, grasshopper sparrows, and song sparrows decreased. Many of these changes can be attributed to the drought in 1988, which altered the habitat making it more suitable for some species and less suitable for others (see Factors Influencing Bird Species Richness and Abundance).

In our field plots, total bird abundance was greater than that reported by others for rowcrop fields (Graber and Graber 1963, Best et al. 1990). This may be due, in part, to differences inherent in the sampling techniques (i.e., size and location of sampling plots and census method) (Bryan and Best, Iowa State University, unpubl. data).

Factors Influencing Bird Species Richness and Abundance

Waterway characteristics

Several habitat characteristics significantly influenced patterns of bird species richness and abundance. Bird species richness was positively correlated with the percent coverage of forbs in waterways both years (1987 : $\underline{r} = 0.58$, 11 df, $\underline{P} = 0.05$; 1988 : $\underline{r} = 0.54$, 9 df, $\underline{P} = 0.02$). In 1987, the abundance of red-winged blackbirds ($\underline{r} = 0.72$, $\underline{P} = 0.01$), American goldfinch ($\underline{r} = 0.68$, $\underline{P} = 0.02$), savannah sparrows ($\underline{r} = 0.68$, $\underline{P} = 0.02$), dickcissels ($\underline{r} = 0.78$, $\underline{P} < 0.01$), song sparrows ($\underline{r} = 0.69$, $\underline{P} = 0.01$), and ring-necked pheasants ($\underline{r} = 0.71$, $\underline{P} = 0.02$) was positively correlated with forb coverage. In 1988, the number of American goldfinch ($\underline{r} = 0.55$, $\underline{P} = 0.01$), common grackles ($\underline{r} = 0.61$, $\underline{P} < 0.01$), American robins ($\underline{r} =$

0.61, $\underline{P} < 0.01$), and brown-headed cowbirds ($\underline{r} = 0.55$, $\underline{P} = 0.01$) was positively related to forb coverage. In 1987, abundances of brown-headed cowbirds ($\underline{r} = 0.76$, $\underline{P} < 0.01$) and indigo buntings ($\underline{r} = 0.81$, $\underline{P} < 0.01$) were correlated with the percent coverage of residue in the waterways, as were abundances of grasshopper sparrows ($\underline{r} = 0.57$, $\underline{P} = 0.01$) and American robins ($\underline{r} = 0.64$, $\underline{P} < 0.01$) in 1988. Also in 1988, the number of vesper sparrows ($\underline{r} = 0.57$, $\underline{P} = 0.02$) and horned larks ($\underline{r} = 0.77$, $\underline{P} < 0.01$) was positively correlated with the percent coverage of bare ground.

Percent grass coverage was the only plant growth form measured in waterways that was negatively correlated with bird abundance. In 1987, fewer song sparrows ($\underline{r} = -0.59$, $\underline{P} = 0.05$), dickcissels ($\underline{r} = -0.64$, $\underline{P} = 0.03$), and red-winged blackbirds ($\underline{r} = -0.64$, $\underline{P} = 0.03$), and in 1988, fewer American goldfinch ($\underline{r} = -0.49$, $\underline{P} = 0.03$), American robins ($\underline{r} = -0.50$, $\underline{P} = 0.03$), brown-headed cowbirds ($\underline{r} = -0.47$, $\underline{P} = 0.04$), common grackles ($\underline{r} = -0.50$, $\underline{P} = 0.05$), and house sparrows ($\underline{r} = -0.50$, $\underline{P}$ 0.03) occurred in waterways with greater grass coverage.

The positive response in bird abundance to greater forb coverage, and often, the concurrent negative response to greater grass coverage, is a documented habitat selection pattern for dickcissels and American goldfinch (Zimmerman 1971, 1982; Wiens 1973; Buhnerkempe 1979; Finck 1984; Kahl et al. 1985). The horned lark is known for its affinity for disturbed ground and other areas with exposed soil (Kahl et al. 1985, Karr 1968). Whitmore (1979) and Kahl et al. (1985) found that residue cover was one of several important components in grasshopper sparrow habitat selection. All of the previously mentioned studies corroborate the relationships we found between bird abundance and habitat variables.

The abundance of some species was strongly related to waterway vegetation height and density (Table 5). In 1987, the abundance of ring-necked pheasants, barn swallows, and

Table 5. Product-moment correlation coefficients comparing bird abundance correlated with vegetation height and density in grassed waterways in central Iowa from 19 June through 22 July 1987-88

	1987 ($\underline{n}$ = 12)[a]		1988 ($\underline{n}$ = 10)	
Species	Height	Density	Height	Density
Ring-necked pheasant	0.87*[b]	0.89*	0.14	- 0.03
Horned lark	- 0.88*	- 0.90*	- 0.23	- 0.23
Barn swallow	0.87*	0.89*	- 0.33	- 0.28
Common yellowthroat	0.71*	0.57	0.76*	0.80*
Red-winged blackbird	0.70*	0.75*	0.67*	0.52
Indigo bunting	- 0.17	- 0.02	0.76*	0.61*
Vesper sparrow	- 0.86*	- 0.85*	- 0.26	- 0.27
Dickcissel	0.20	0.28	0.84*	0.69*
Total abundance	0.12	0.25	0.71*	0.61*

[a]Number of waterways sampled.

[b]Significant ($\underline{P} \leq 0.05$) coefficient for correlation analysis of bird abundance vs. vegetation height and density.

red-winged blackbirds was positively correlated only with vegetation height and density, whereas the abundance of common yellowthroats was positively correlated with vegetation height only. In 1988, numbers of common yellowthroats, indigo buntings, dickcissels, and total bird abundance were positively correlated with vegetation height and density, but red-winged blackbird abundance was related only to vegetation height. Tall, dense vegetation is required by red-winged blackbirds, indigo buntings, common yellowthroats, and dickcissels (Bent 1953, Stewart 1953, Albers 1978, Buhnerkempe 1979, Kahl et al. 1985). Red-winged blackbirds and common yellowthroats were the only species whose abundances were positively correlated with a vegetation variable (height) both years (Fig. 1).

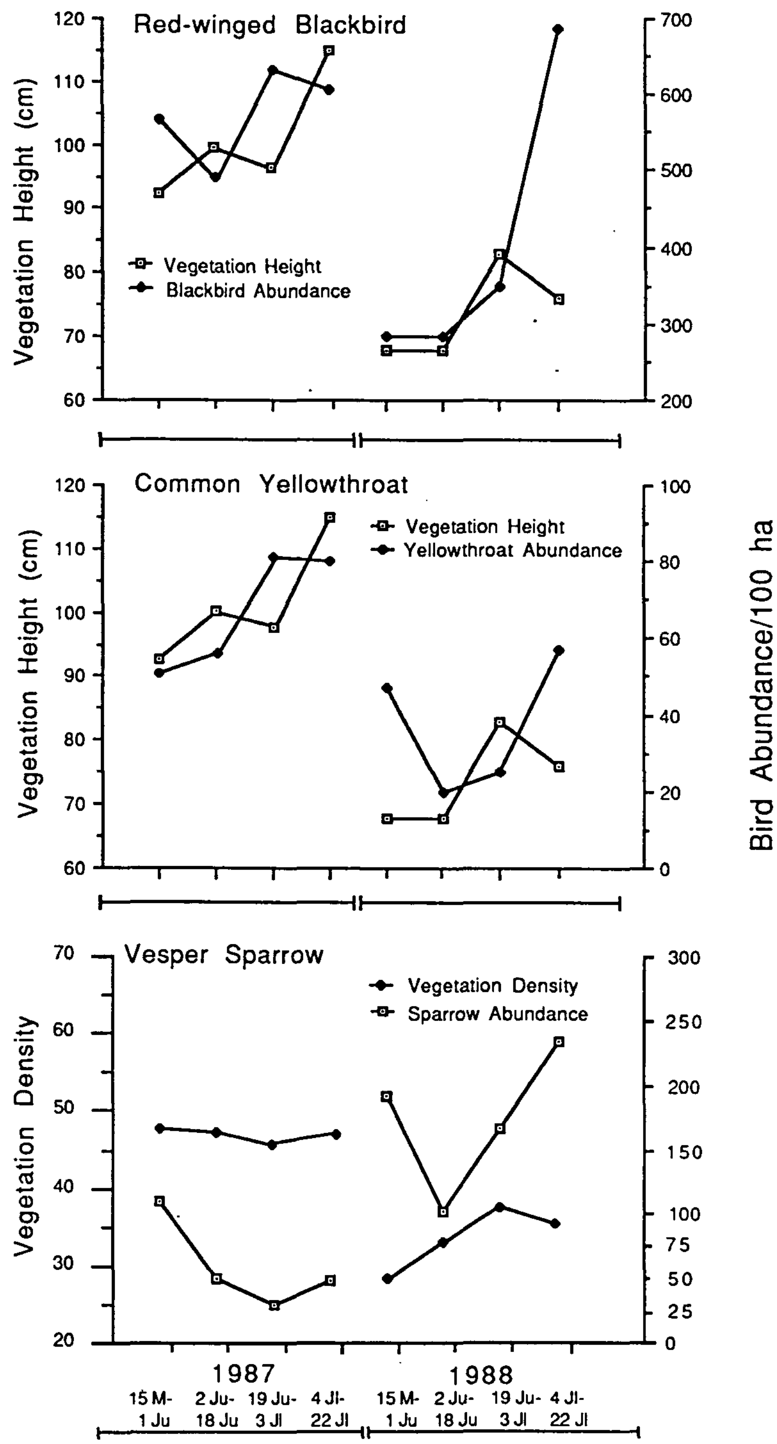
Vesper sparrow (Fig. 1) and horned lark abundance was negatively correlated with vegetation height and density in 1987, when climatic conditions allowed the vegetation to more fully reach its growth potential (Table 2). Vesper sparrows (Best and Rodenhouse 1984, Reed 1986) and horned larks (Kahl et al. 1985) prefer habitats with short, sparse vegetation; therefore, waterways with taller, more dense vegetation were less suitable for these species. That vesper sparrow and horned lark abundances were not correlated with vegetation height and density in 1988 could have been because the drought prevented the vegetation in waterways from growing beyond suitable levels for these species.

Bird abundance and species richness were not significantly different among waterway length or width classes either year. The minimum width of 9 m, recommended for waterway construction, and the minimum length of 200 m, chosen for our study, appeared to be sufficient for birds to use waterways.

Adjoining habitat

The habitat adjoining waterways did not significantly influence total bird abundance or the number of species in the waterways. Birds were most abundant, however, in the ends of

Figure 1. Mean red-winged blackbird and common yellowthroat abundance during approximately 2- week intervals from 15 May through 22 July in relation to mean vegetation height, and mean vesper sparrow abundance in relation to vegetation density in grassed waterways. Abundance comparisons were made during a year with normal rainfall (1987) in 24 waterways and during a drought year (1988) in 20 waterways in central Iowa


Red-winged Blackbird
Vegetation Height
Blackbird Abundance
Vegetation Height (cm)
Common Yellowthroat
Vegetation Height
Yellowthroat Abundance
Bird Abundance/100 ha
Vesper Sparrow
Vegetation Density
Sparrow Abundance
Vegetation Density
1987
1988
15 M- 1 Ju
2 Ju- 18 Ju
19 Ju- 3 Jl
4 Jl- 22 Jl

waterways where they adjoined a habitat type different from the waterway. This will be discussed further in Spatial Patterns. When bird abundance and the number of species in the 5 different adjoining habitat types were compared, only the abundance of indigo buntings in waterways differed significantly between adjoining habitat types ($\underline{F} = 3.39$; 4, 15 df; $\underline{P} = 0.04$). Indigo buntings were encountered more often in waterways associated with woodlots than with any other habitat type (woodlots: $\bar{x} = 146$ birds/100ha; pastures: $\bar{x} = 22$; farmsteads: $\bar{x} = 14$; herbaceous fencerows: $\bar{x} = 3$; creeks: $\bar{x} = 0$).

Adjoining habitats also were grouped based on the presence or absence of trees. In 1987, barn swallows were significantly more abundant in waterways adjoining habitats without trees (trees absent: $\bar{x} = 97$ birds/100 ha; trees present: $\bar{x} = 24$; $\underline{F} = 6.75$; 1, 7 df; $\underline{P} = 0.04$). Sedge wrens were observed more often in waterways adjoining habitats with trees (trees absent: $\bar{x} = 0$ birds/100 ha; trees present: $\bar{x} = 15$; $\underline{F} = 5.42$; 1, 7 df; $\underline{P} = 0.05$). Sedge wrens were found primarily in waterways adjoining creeks, which is included in the category of habitats with trees. These associations are consistent with the habitat preferences documented for these species (Walkinshaw 1935, Kahl et al. 1985, Dinsmore et al.1984). In 1988, the total abundance of birds was significantly higher in waterways adjoining habitats with trees (trees absent: $\bar{x} = 1{,}019$ birds/100 ha; trees present: $\bar{x} = 1{,}912$; $\underline{F} = 4.35$; 1, 18 df; $\underline{P} = 0.05$) . Some species typical of woodland areas (e.g., rose-breasted grosbeak, northern oriole, and hairy woodpecker) were observed only in waterways adjoining treed habitats, but they were seen too infrequently for their numbers to differ significantly between the 2 adjoining habitat categories.

Surrounding cropland

Waterways are small strips of cover and, as such, are more subject to the influence of surrounding vegetation than large contiguous blocks of habitat. Although the amount and type of crop residue in the fields surrounding the waterways did not significantly affect bird abundance in waterways, the surrounding crop type did influence the occurrence of some species. In 1987, song sparrows and vesper sparrows were observed more often in waterways in cornfields than in those in soybean fields (SS: corn $\bar{x}$ = 266 birds/100 ha; soybeans $\bar{x}$ = 43; t = 2.23, 14 df, P = 0.04; VS: corn $\bar{x}$ = 221; soybeans $\bar{x}$ = 18; t = 2.37, 11 df, P = 0.04) . In 1988, waterways in cornfields also had significantly more dickcissels than waterways in soybean fields (corn $\bar{x}$ = 606 birds/100 ha; soybeans $\bar{x}$ = 224; t = 2.21, 18 df, P = 0.04), whereas waterways in soybean fields had more western meadowlarks than waterways in cornfields (cornfield waterways: $\bar{x}$ = 11; soybean field waterways: $\bar{x}$ =108; t = 2.24, 12 df, P = 0.04). In the case of cornfields, corn plants often were used as singing perches by males. All of the previously mentioned species, however, responded to the crop type early in the study before the crop plants were tall enough to serve as song perches or had even begun to develop their characteristic growth form. Consequently, site-fidelity may have caused these species to choose fields based on previous vegetation and not the present crop. Strong philopatry, or site-fidelity, has been demonstrated and discussed in several species of grassland birds (e.g., Lanyon 1957, Best 1986).

Bird abundance and the number of species also were correlated with crop height in the fields surrounding the waterways. In 1987, species richness (r = 0.59, 11 df, P = 0.05) and the abundance of dickcissels (r = 0.99, P < 0.01) and ring-necked pheasants (r = 0.71, P = 0.02) were postively correlated with crop height, as was the abundance of barn swallows (r = 0.91, P < 0.01) and indigo buntings (r = 0.71, 9 df, P = 0.01) in 1988. As crops grew, they may have enhanced the vegetation structure surrounding waterways, thereby increasing the attractiveness of the waterways. For the dickcissel, as the growing season progresses, soybeans may provide the forb component preferred for nesting habitat, and corn may provide suitable singing perches (Kahl et al. 1985).

In 1987, 66% (16) of the waterways were adjacent to areas of various sizes that had been taken out of crop production (i.e., diverted) and planted to alfalfa (56%), oats (31%), or grass mixes (13%). Half of the diverted areas associated with the waterways were planted as a field border about 50m wide and only came into contact with the waterways where the waterways connected to the fenceline. The dickcissel was the only species significantly more abundant in waterways associated with diverted field borders than in those without such diverted areas (diverted borders: $\bar{x}$ = 618 birds/100 ha; no diverted borders: $\bar{x}$ = 236; t = 3.17, 13 df, P = < 0.01). Occasionally (17%) these diverted areas consisted of strips planted the entire length of the waterway on one or both sides. The total abundance of birds (diverted areas: $\bar{x}$ = 2,528 birds/100 ha; no diverted areas: $\bar{x}$ = 1,679; t = 2.14, 15 df, P = 0.05) and the abundance of dickcissels (diverted areas: $\bar{x}$ = 630 birds/100 ha; no diverted areas: $\bar{x}$ = 153; t = 3.25, 11 df, P = < 0.01) and grasshopper sparrows (diverted areas: $\bar{x}$ = 163 birds/100 ha; no diverted areas: $\bar{x}$ = 17; t = 2.41, 9 df, P = 0.04) were significantly greater in waterways next to these diverted areas than in those not associated with such areas. The affinity of the dickcissel to waterways associated with either type of diverted area is understandable because most of these areas were planted to forbs (i.e., alfalfa) which is an important habitat component for the dickcissel (Zimmerman 1971; Wiens 1973; Finck 1984; Frawley 1989).

Agricultural disturbance

Disturbance is an aspect of the agricultural environment important to birds. One type of disturbance in waterways is caused by tractors driving through the waterways while making passes over the fields. If crop rows are planted parallel to a waterway, disturbance to birds using the waterway is minimal because the tractor is driven along the side of the waterway. In contrast, if the crop rows are planted perpendicular to the waterway, the tractor is driven across the waterway to continue down the rows. The frequency of this disturbance varies with the type of tillage practice, but usually entails 5-7 trips across the field and waterway (Best 1986). Because these trips are spaced at fairly regular intervals throughout the early part of the breeding season and cause considerable disturbance of nesting (Rodenhouse and Best 1983). Thus one would expect the increased disturbance associated with perpendicular row orientation to discourage bird use of these waterways, and our census results verified this (Table 6). The number of species was less in waterways in fields with rows orientated perpendicular to the waterway in both 1987 and 1988. Additionally, in 1988 the abundance of red-winged blackbirds and song sparrows in waterways in fields with perpendicular rows was less than that in those with parallel rows. In contrast, horned lark, vesper sparrow, and barn swallow numbers were higher in waterways bounded by perpendicular crop rows. Both horned larks and vesper sparrows nest in agricultural fields and prefer the bare ground and more sparse vegetation found in crop fields early in the growing season (Wiens 1969, Rodenhouse and Best 1983, Basore et al. 1986). The more often that waterways were crossed by tractors, the more likely that the vegetation in the waterways would be damaged, leaving bare spots and sparse vegetation growth, thereby increasing the attractiveness of the waterways to these species. Although the preference of horned larks and vesper sparrows for waterways bounded by perpendicular crop rows also was evident in 1987, it was not significant. Drought conditions in 1988 may have magnified any vegetation damage caused by tractors thus making the waterways more suitable for species preferring sparsely vegetated sites. In 1988, waterways in fields with perpendicular rows had greater bare ground coverages ($\bar{x}$ = 5%, SE = 6.8, n = 12) than those in fields with parallel rows ($\bar{x}$ = 2%, SE = 2.9, n = 7); however, the difference was not significant (P = 0.22)

Mowing is another disturbance important to birds in an agricultural environment. Timing of mowing in waterways is erratic because this task is usually a low priority for

Table 6. Significant ($\underline{P} \leq 0.05$) differences in the number of birds observed/100 ha and the number of species using grassed waterways in crop fields with crop rows oriented parallel vs. perpendicular to the waterway from 15 May through 31 July 1987 - 88 in central Iowa

	1987				1988			
	Parallel rows ($\underline{n}$ = 7)[a]		Perpendicular rows ($\underline{n}$ = 4)		Parallel rows ($\underline{n}$ = 4)		Perpendicular rows ($\underline{n}$ = 8)	
	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE
Number of species	7.44	2.40 *[b]	6.21	2.04	7.33	2.03 *	4.56	3.26
Horned lark	7.83	31.47	15.54	54.49	23.62	56.14 *	127.4	326.02
Barn swallow	85.23	119.73	68.04	178.53	90.71	134.28 *	344.75	894.08
Red-winged blackbird	672.23	528.47	663.37	552.41	619.05	547.57 *	234.25	352.06
Vesper sparrow	84.83	119.77	102.63	256.04	76.43	141.19 *	185.82	288.03
Song sparrow	142.13	164.11	188.58	250.95	77.19	154.23 *	5.57	22.81

[a]Number of waterways sampled.

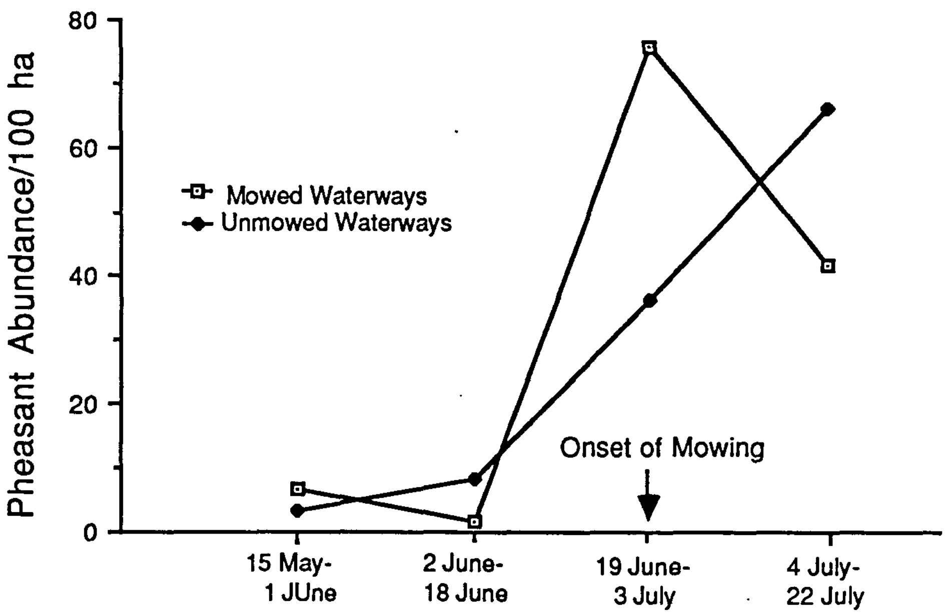
[b]* = Significant difference ($\underline{P} \leq 0.05$, student's t-test) comparing relative abundance between waterways in fields with crop rows oriented parallel versus perpendicular to the waterway.

farmers and occurs when they have finished other more pressing tasks. Although waterways were typically mowed during or after the 19 June- 3 July period, mowing affected the waterway habitat from the outset of the breeding season because mowing the previous year caused the current year's mowed waterway vegetation height and density to be lower initially than in unmowed waterways (Table 2).

Mowing influences birds greatly because of the dramatic alteration of the habitat. When completely mowed waterways were compared with those not mowed, certain bird species showed opposite preferences for these practices. Dickcissels were significantly more abundant in unmowed waterways than in mowed waterways during 2 - 18 June and 19 June - 3 July in 1988 (unmowed: $\bar{x}$ = 437 birds/100 ha; mowed: $\bar{x}$ = 94; t = 2.78, 8 df, P = 0.01 and unmowed: $\bar{x}$ = 433; mowed: $\bar{x}$ = 114; t = 2.51, 14 df, P = 0.02, respectively), but not until 4 - 22 July in 1987 (unmowed: $\bar{x}$ = 323 birds/100 ha; mowed: $\bar{x}$ = 81; t = 2.59,12 df, P = 0.02). Dickcissels may have appeared in these waterways after being forced out of hayfields, roadsides, and other waterways that were mowed. In 1987, common yellowthroats (unmowed: $\bar{x}$ = 145 birds/100 ha; mowed: $\bar{x}$ = 0; t = 2.84,10 df, P = 0.02) and red-winged blackbirds (unmowed: $\bar{x}$ = 783 birds/100 ha; mowed: $\bar{x}$ = 42; t = 3.37, 10 df, P = < 0.01) also were more abundant during 4 - 22 July in unmowed than mowed waterways.

Mowing has an adverse effect on all species that respond positively to vegetation height and/or density. For example, ring-necked pheasant abundance was positively correlated with vegetation height (Table 5), and in mowed waterways, ring-necked pheasant numbers peaked during 19 June - 3 July and then dropped noticeably during 4 - 22 July (Fig. 2). Only 30 % of these waterways had been mowed by 19 June - 3 July, but by 4 - 22 July, the remaining waterways were mowed. In contrast, in unmowed waterways, ring-necked pheasant abundance peaked during 4 - 22 July. Similar abundance patterns were observed in

Figure 2. Mean number of ring-necked pheasants/100 ha using mowed and unmowed grassed waterways at approximately 2-week intervals from 15 May through 22 July 1987-88 in central Iowa



80
60
40
20
0
Pheasant Abundance/100 ha
Mowed Waterways
Unmowed Waterways
Onset of Mowing
15 May-
1 JUne
2 June-
18 June
19 June-
3 July
4 July-
22 July

the other species of birds whose abundances also were positively correlated with vegetation height and/or density (Table 5).

In contrast to the species responding negatively to mowing, grasshopper sparrows were more abundant in completely mowed than unmowed waterways from the beginning of the breeding season in 1987 (unmowed: $\bar{x}$ = 47 birds/100 ha; mowed: $\bar{x}$ = 235; t = 2.55, 16 df, P = 0.02). Vesper sparrows (unmowed: $\bar{x}$ = 8 birds/100 ha; mowed: $\bar{x}$ = 113; t = 2.28,16 df, P = 0.04) also were more abundant in completely mowed waterways during 4 - 22 July, 1987. Grasshopper sparrows and vesper sparrows prefer the short vegetation (Whitmore 1981, Best and Rodenhouse1984, Kahl et al. 1985, Reed 1986, Frawley 1989) provided and maintained by mowing.

Completely mowed waterways also were compared to those only spot mowed to control weeds. In 1987, only total bird abundance differed, and was greater in waterways that were spot mowed (spot mowed: $\bar{x}$ = 3,082 birds/100 ha; completely mowed: $\bar{x}$ = 1,830; t = 2.61, 11 df, P = 0.02). This difference in total bird abundance was observed from the onset of the breeding season. Vegetation in spot mowed waterways was similar to that in unmowed waterways; consequently, there is more vegetation structure at the beginning of the growing season. In addition, spot mowing may provide a greater diversity in vegetation structure by having mowed and unmowed areas interspersed, thereby attracting a more diverse assemblage of birds.

Temporal changes

Bird species richness, total bird abundance, and the abundance of some individual bird species were influenced by aspects of the waterway and surrounding cropland that changed over time, such as crop and vegetation height (Table 7). Vegetation height is an important structural feature influencing habitat selection by grassland birds that can change the

Table 7. Significant ($\underline{P} \leq 0.05$) changes in the numbers of species and birds observed/100 ha in grassed waterways over the 4 from 15 May through 22 July 1987-88 in central Iowa

	15 May - 1 June		2 June - 18 June		19 June - 3 July		4 July - 22 July		
	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\underline{P} > \underline{F}$[a]
1987 (n = 24)[b]									
Species	5	2 C [c]	6	2 B	7	2 B	8	3 A	< 0.01
Upland sandpiper	0	0 B	0	0 B	0	0 B	13	39 A	0.04
Barn swallow	22	60 B	34	75 B	57	96 B	102	146 A	< 0.01
Indigo bunting	0	0 B	6	29 B	13	31 B	41	110 A	0.03
1988 (n = 20)									
Species	3	2 C	4	2 B	5	3 AB	6	3 A	< 0.01
House sparrow	11	48 B	3	12 B	43	191 AB	76	13 A	0.04
Dickcissel	103	261 B	336	366 A	344	374 A	334	455 A	< 0.01
Total abundance	1262	1046 B	1269	711 B	1461	815 B	2227	2397 A	0.03

[a]ANOVA comparing relative abundance and species richness among the 4 intervals.

[b]Number of waterways sampled.

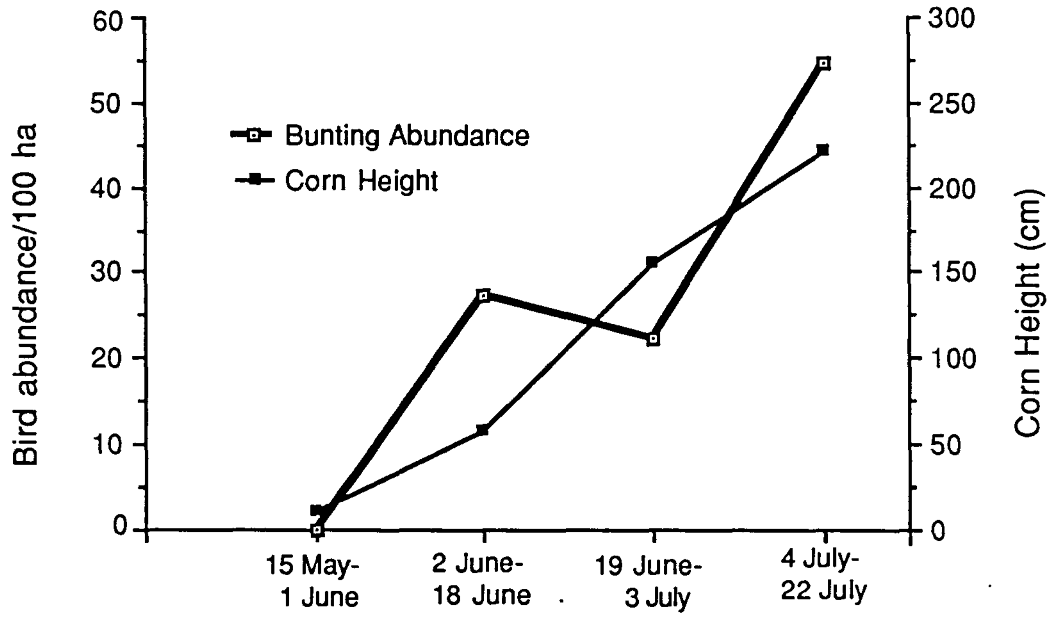
[c]Means within a row followed by different letters are significantly different ($\underline{P} \leq 0.05$, Duncan's multiple range test).

suitability of a particular area over time (Wiens 1969, Buhnerkempe 1979). Species richness differed between time periods for both years of the study, whereas total bird abundance differed only during 1988. In 1987, barn swallow, upland sandpiper, and indigo bunting abundances significantly increased from 15 May to 22 July, but in 1988, dickcissels and house sparrows increased in numbers over this time.

One factor potentially responsible for the differences between years in the species that showed temporal shifts in abundance was the drought in 1988 and its impact on the habitat. The height and density of waterway vegetation differed significantly between years because of the drought (Table 3), and this difference probably influenced temporal shifts in habitat use by some species. Indigo buntings prefer tall, dense vegetation (Kahl et al. 1985), and in 1987, the growth of the vegetation in and adjacent to waterways evidently increased the attractiveness of these habitats as the season progressed. That indigo bunting abundance did not increase over time in 1988 may have been because vegetation growth that year was slowed by the drought. This, in turn, may have made the waterways less attractive than a more suitable habitat, such as shrubby or wooded areas (Carey and Nolan 1979, Kahl et al. 1985). Although indigo bunting abundance did not differ significantly over time in 1988, their numbers were closely related to crop height ($r = 0.71$, 9 df, $P = 0.01$). Both years, indigo buntings were only observed in waterways surrounded by corn and were not present in the waterways until the second period (Fig. 3). At that time, corn may have begun to simulate the woody vegetation structure required by the buntings for nesting and song perches (Carey and Nolan 1979, Kahl et al. 1985).

Another factor may have contributed to the seasonal increase in dickcissels and total bird abundance in 1988, when habitat characteritics did not seem to be as favorable. That year, farmers were given permission to mow early the land enrolled in government set-aside programs as a result of reduced hay production caused by the drought. Grassland birds

Figure 3. Mean indigo buntings abundance in 20 grassed waterways in relation to mean corn height at approximately 2-week intervals from 15 May through 22 July 1988 in central Iowa


Bird abundance/100 ha
60
50
40
30
20
10
0
Bunting Abundance
Corn Height
300
250
200
150
100
50
0
Corn Height (cm)
15 May-
1 June
2 June-
18 June
19 June-
3 July
4 July-
22 July

using these set-aside areas were forced to concentrate in the remaining fragments of unmowed vegetation (e.g., unmowed waterways).

Spatial patterns

The number of species and bird abundance differed among waterway segments (Table 8). Total bird abundance differed between segments for both years (1987: $F = 3.72$; 3, 21 df; $P = 0.03$ and 1988: $F = 5.69$; 1, 17 df; $P = 0.03$) (Table 8). In 1987, red-winged blackbird abundance ($F = 5.43$; 3, 21 df; $P = 0.006$), and in 1988, bird species richness ($F = 12.40$; 1, 17 df; $P < 0.01$) and dickcissel abundance ($F = 3.86$; 1, 17 df; $P = 0.07$) differed among segments. A Duncan's multiple range test (SAS Inst. Inc. 1985) was used to determine which segments differed significantly from the others. In 1987, red-winged blackbird and total bird abundance were greater in the waterway segment adjoining another habitat type than in any of the segments farther removed from the edge habitat. In 1988, the number of bird species, dickcissel abundance, and total bird abundance also were greatest in the waterway segment next to the edge habitat. Greater species richness and bird abundance are often associated with edge habitat (Leopold 1933; Gates and Gysel 1978; Best et al. 1990).

Table 8. Significant ($\underline{P} \leq 0.05$) differences in the numbers of species and birds observed/100 ha in 100-m long segments[a] of grassed waterways from 15 May through 22 July 1987-88 in central Iowa

	1987 segments											
	0 - 100 m			101 - 200 m			201 -300 m			301 - 400 m		
	$\bar{x}$	SE		$\bar{x}$	SE		$\bar{x}$	SE		$\bar{x}$	SE	
Bird species	3	2	A[b]	3	2	A	3	2	A	2	1	A
Red-winged blackbird	1250	1023	A	647	750	B	673	567	B	548	457	B
Dickcissel	458	432	A	345	297	A	374	365	A	303	247	A
Total abundance	2790	2352	A	1769	823	B	2224	2394	AB	1777	1895	B

[a]Segment distances were measured from where the waterway adjoined another habitat type.

[b]Means within a row followed by different letters are significantly different ($\underline{P} \leq 0.05$, Duncan's multiple range test).

1988 segments			
0 - 100 m		101 - 200 m	
$\bar{X}$	SE	$\bar{X}$	SE
3	1 A	2	1 B
786	893 A	258	198 A
471	409 A	303	349 B
2586	2753 A	1315	911 B

MANAGEMENT IMPLICATIONS

An important consideration in waterway management is the amount of forbs present. Most forbs present in waterways are invading weeds. If these weeds are not on the state noxious weed list and are not a seed source for problem weeds in the crop field, they should be left for their benefits to wildlife. Some forbs in waterways that serve as nesting sites and/or food sources are: common milkweed, sweet clover, curly dock, tall coneflower, and daisy fleabane (Martin et al. 1951). Waterways are sometimes planted with a legume in the grass mixture for the nitrogen-fixing qualities of the legume; however, this practice is often discouraged because legumes are short-lived, leaving bare spots exposed to erosion (U.S.D.A. 1960). Cool season grasses, like smooth brome, need large amounts of nitrogen which can be provided efficiently and naturally by the addition of alfalfa to the grass mix (Barnhart 1986). In many cases, the benefits of nitrogen production by the legume may outweigh the cost of bare spots. Although alfalfa is short-lived, it can be reseeded. Alfalfa also provides more height than other legumes recommended for waterways, and has been reported as an attractive nesting habitat for many grassland species when planted alone or in a mixture with smooth brome (Regenscheid et al. 1987, Warner et al. 1987, Frawley 1989). Consequently, for many bird species, alfalfa would be an attractive addition to smooth brome plantings in grassed waterways.

The timing of waterway mowing is also important in relation to bird abundance, especially in light of current recommendations for wildlife. The recommendation is to mow after 15 July, but 53 % of all species observed and 100 % of breeding species were at peak abundance in the waterways during 4 - 22 July. In light of this and the documented bird responses to mowing of waterways (see Agricultural Disturbance, Fig. 2), waterways should not be mowed until the end of August or early September. This will minimize the negative impacts on avian production in and use of waterways. Conversely, mowing should not be delayed until mid-September because mowing that late would not allow sufficient regrowth of the vegetation to provide adequate cover for birds in the winter and following spring.

Unmowed waterways are important habitat for birds in mid to late summer for 2 reasons. First, by this time, habitats similar to waterways (e.g., hayfields and roadside ditches) often have been mowed, thereby concentrating the birds in the remaining unmowed habitat such as unmowed waterways. Evidence for this is seen in the large numbers of birds observed in the waterways at this time. Also, in a recent study, banded male dickcissels were observed moving from alfalfa fields after mowing to unmowed waterways and fencerows, where they established new territories (L. D. Igl, Dept. of Animal Ecology, Iowa State Univ., pers. commun.) Secondly, unmowed smooth brome has been shown to have the highest abundance of insects nutritious for young birds when compared with other grass types and alfalfa (Regenscheid et al. 1987). The predominant grass in the waterways was smooth brome; consequently, the increase in bird numbers could reflect feeding juveniles and adults gathering food for their young. Warner and Joselyn (1986) found that ring-necked pheasant nesting success was higher in smooth brome roadsides than the combined nesting success in hayfields, pastures, small grains, and other strip cover. Grass waterway habitats are comparable to roadsides, and, if left unmowed, ring-necked pheasants may also have similar nesting success in waterways. Three of 5 ring-necked pheasant nests were successful in our waterways (see Section II).

Although mowing may adversely affect nesting success and/or habitat quality for some bird species, it is sometimes economically necessary for the farmer and also creates a habitat more suitable for some species, such as vesper and grasshopper sparrows. Where mowing is used primarily for weed control, spot mowing should be considered as an alternative because it has less impact on bird abundance than complete mowing. Furthermore, the distance that mowing occurs from the edge habitat also should be considered. Because bird abundance is greatest within the first 100 m of the waterway where it adjoins another habitat, mowing should be avoided in this zone and preferably in the next 50-100 m, which could serve as a buffer.

Crop rows that are parallel to waterways cause less disturbance than those that are perpendicular and thereby increase bird abundance. Row orientation is important for waterway maintenance, however, in addition to its influence on bird abundance. When rows are perpendicular to the waterway, soil from the field will run off into the waterway. Over time, this will fill in the waterway so that it loses its trough-like shape and, subsequently, can not properly channel excess water off the field. All waterways fill in over time, but when crop rows are perpendicular to the waterway, this happens more quickly, and the only recourse is to undergo the expense and effort to reshape and replant the waterway. In contrast, if rows run parallel to the waterway, they do not carry soil directly into the waterway. Also, rows that parallel waterways are often associated with contour planting (i.e., crop rows that follow the contour of the land), a practice which is an important method of preventing soil erosion. If, however, the waterway is oriented lengthwise down a hill rather than lying horizontally in a low area between hills, the rows must run perpendicular to the waterway to achieve contour planting. In this case, the benefits of contour planting in preventing soil erosion may outweigh the increased disturbance to the birds.

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SECTION II. PRODUCTIVITY OF BIRDS USING GRASSED WATERWAYS IN IOWA ROWCROP FIELDS

ABSTRACT

Grassed waterways have been used for decades to prevent soil erosion in agricultural cropland, but their benefits to wildlife had not been evaluated previously. We documented bird species nest density and success during the breeding season in 24 waterways in central Iowa. The waterways were planted predominately to smooth brome and were in cornfields and soybean fields. Ten species were observed nesting in the waterways; the red-winged blackbird (Agelius phoeniceus) and dickcissel (Spiza americana) were the most common. One hundred and seventy-one nests were found, with a nest density of 1,295 nests/100 ha. The extended Mayfield method was used to determined nest success rate, which was 8.4% for red-winged blackbirds and 22.0% for dickcissels. The 2 greatest causes of nest loss were predation, which accounted for 57% of all losses, and mowing accounting for 16% of all losses. Annual productivity in waterways was estimated at 1.03 young fledged/female/season for red-winged blackbirds, and 2.23 for dickcissels. Waterways may be ecological traps for these species under current management practices, but nest success might be increased by delaying mowing until late August or early September, or by not mowing annually and using spot herbicide spraying or spot mowing to control weeds. Other management strategies such as establishing and maintaining wider waterways also may increase nest success.

INTRODUCTION

Grassed waterways have been promoted by the U.S. Soil Conservation Service to prevent soil erosion since 1947 (Temple 1983). They are channels (natural or constructed) that have been shaped to transport water at nonerosive velocities from fields, diversions, terraces, and roadside ditches. Grass species planted in the channel are determined by geographic location and erosion potential. These species are predominantly cool season grasses because of their quick establishment and even, dense growth (U.S.S.C.S. 1975).

From the outset, waterways have been promoted for their benefits to wildlife, particularly ring-necked pheasants (scientific names given in Table 1) and other upland game birds. Nest success has been reported for some linear habitats associated with agricultural cropland (e.g., fencerows: Allen 1941, Shalaway 1985; shelterbelts: Yahner 1982), but prior to our study, bird nest densities and nesting success in grassed waterways had not been documented. Basore et al. (1986) included grassed waterways in an assessment of bird nesting densities and nesting success, but the waterways were not distinguished from other types of strip cover. High densities of nesting birds have been found in narrow habitats comparable to grassed waterways (e.g., Dow 1969, Basore et al. 1986). This also may be true for waterways, particularly for grassland bird species.

High densities of nesting birds are not necessarily synonymous with high reproductive output. In some agricutural areas, increased disturbance from farming practices decreases nesting success to far below the level necessary to sustain the population (Rodenhouse and Best 1983, Frawley 1989). Predation may also be higher in grassed waterways because nest predators may actively search linear habitats (Allen 1941, Davison 1941, but see Shalaway 1985, Snow and Mayer-Gross 1967).

Wiens and Rotenberry (1981) believed that species are comprised of "source" populations, which live in high quality habitat enabling them to reproduce above the level necessary to sustain the species, and "sink" populations, which are in substandard habitat hindering their reproductive success so that the population is unable to sustain the species. Linear habitats may prove to be habitat for both source and sink populations depending on the characteristics of the habitat, the species of bird in question, and the way in which the habitat is managed.

If populations inhabiting waterways are sink populations, then waterways may serve as "ecological traps." Gates and Gysel (1978) and Best (1986) suggested that some man-made areas can be similar in physical and/or vegetational structure to preferred nesting habitats, but, in fact, harbor some excessive cause of nest failure, absent or scarce in the natural habitat, that greatly reduces reproductive success. Causes of failure in these "traps" include predation and human disturbance, both possible in waterways. In agricultural systems, particularly, a major cause of nest failure is human disturbance (e.g., mowing, tillage practices) (Rodenhouse and Best 1983, Rogers 1983, Best 1986, Frawley 1989). Waterways with vegetative characteristics similar to grasslands may lure birds, only to expose them to increased predation and/or human disturbance. However, waterways are man-made and, as such, various aspects of vegetation structure and human disturbance can be managed to reduce the likelihood that the waterways will be ecological traps.

The need for research to answer these questions and define management guidelines became even more important with the passage of the 1985 Farm Bill. The Conservation Compliance Provision requires landowners to implement a conservation plan if they continue to farm annually tilled crops on highly erodible land. This is expected to increase conservation tillage, terracing, and the number of grassed waterways (U.S.D.A. 1986). There are 99 counties in Iowa, and in Marshall County alone (part of our study area), at least

57 waterways have been constructed from 1983 through 1987 (D. Baloun, U.S.S.C., pers. commun.). In light of the high rate of fencerow removal (Vance 1976), the increase in the number of grassed waterways will assume even greater importance as wildlife habitat in agricultural areas. Therefore, management guidelines are needed to establish and maintain the growing number of grassed waterways to improve their value to wildlife.

The objectives of our study were: 1) to ascertain which avian species nest in grassed waterways and at what nesting densities, 2) to determine if grassed waterways serve as suitable nesting habitat, 3) to assess the influence of various waterway characteristics on nesting density and success, and 4) to develop waterway management strategies for landowners and others interested in enhancing these areas for wildlife.

METHODS AND MATERIALS

Study Area and Site Selection

The 24 waterways chosen for study were in Story and Marshall counties in central Iowa. This area is nearly level to gently rolling. The average daily maximum temperature in summer is 30° C. Total annual rainfall averages 86 cm, with 61 cm of this falling from April through September (Oelmann 1981). Waterways were selected in corn or soybean fields because these constitute about 75% of the cropland in Iowa (U.S.D.A. 1988). Also, fields with reduced tillage (i.e., no fall plowing) were chosen to avoid extremes in tillage practices that might influence birds' use of the waterways (Basore et al. 1986). Reduced tillage is the prevailing practice in Story and Marshall counties.

Before choosing the study waterways, a random sample of 60 waterways in Story and Marshall counties that met U.S. Soil Conservation Service specifications (U.S.S.C.S. 1975) was characterized on the basis of plant species seeded in the waterway, the waterway configuration (linear vs. dendritic), and whether or not the waterway was connected to other strip cover (see Section I). From this random sample the predominant waterway characteristics were determined, i.e., they were planted to smooth brome (Bromus inermis), straight, and connected to strip cover (additional details of the waterway selection process are given in Section I). The waterways also were trapezoidal or parabolic in cross section (according to specifications), varied in length (150 to 900 m), and ranged from 9 to 30 m wide. An new sample of 24 waterways (1987: n = 12, 1988: n = 12) was then chosen for study based on the predominant charactristics, in addition to characteristics of width and length in 1987 and adjoining habitat type in 1988.

In 1987, 12 waterways were chosen for study based on width and length. To facilitate comparing variables measured within each waterway, the waterways were grouped into 6 classes based on waterway length and width. The ranges of the 6 classes were determined by using the original random sample of waterways, with an effort made to balance the number of waterways within each class and the range of each class. The width classes were 9.0-11.5 m (28% of the total random sample), 12.0-14.5 m (46%), and 15.0-30 m (26%); and length classes were 60-304 m (27%), 305-609 m (28%), and >609 m (45%). Because certain widths and lengths were more prevelant than others, the most prevelant width class was used when comparing among length classes and vice versa. Thus, waterways chosen for the 3 width classes were all from the >609 m length class (i.e., length was held constant). Likewise, waterways selected for the 3 length classes were all from the 12.0-14.5 m width class.

In 1988, we selected 12 other waterways based on the habitat types adjoining the ends of the waterways. Five habitat types were chosen for study with 2 waterways in each: farmsteads, creeks, woodlots, pastures, and herbaceous fencerows. Two additional waterways did not abut other habitats, but were isolated in the crop fields. Also, when using these habitat types to analyze the 1987 data, one additional category was added--shrubby fencerows. After preliminary analysis, the waterways were consolidated into 2 habitat groups determined by presence or absence of trees and other brushy cover, which is known to greatly influence avian species composition and abundance in agricultural areas (Best 1983).

Nest Searching and Monitoring

Nest were found by visually searching strips 1 m wide until the waterway had been completely traversed. Once found, nests were marked by placing flags on the waterway borders. This reduced predation that might have occurred if the flags had been placed near the nests (e.g., Picozzi 1975, Hamas 1984). Nest searches were conducted on each waterway twice a month from mid-May through early August.

Nests were monitored every 3-4 days until they were no longer active. Nests were approached from a different direction on each visit to avoid making trails to the nest and, consequently, increasing predation. To minimize desertion, ring-necked pheasant nests were observed from a distance without flushing the hen until the nests were no longer active. The cause of failure was determined for unsuccessful nests by assessing the integrity of the nest, presence and condition of eggshell fragments, and any disturbance to the surrounding area (Rearden 1951, Best and Stauffer 1980). Causes of nest failure were categorized as: abandonment, predation, mowing, weather, farm machinery, or cowbird parasitism.

Nest success was calculated by using the extended Mayfield method (Mayfield 1975, Johnson 1979) and MICROMORT, a computer program developed by Heisey and Fuller (1985). These methods were used to determine daily and interval survival rates, as well as mortality rates for specific causes of nest failure. The percent of nest loss due to individual sources of mortality was calculated following Heisey and Fuller (1985). Our sample sizes were too small to partition the nesting cycle into separate intervals for the egg-laying, incubation, and nestling periods; therefore, we assumed a constant survival rate for the entire nesting cycle (Klett and Johnson 1982). To compare our survival rates with those reported by others, we used a 2-tailed Z-test and compared daily survival rates. If daily survival rates could not be determined from the literature, and only apparent success rates were available from other studies, the apparent rates are given as a point of reference but not compared with our study results. To determine nest success, only active nests (nests containing at least 1 host egg or young) were used. A nest was considered successful if it fledged at least 1 host young. Of the 171 nests located, 119 were used for analysis because they were active when found, the cause and timing of failure could be determined, and they were not destroyed by an observer. The remaining 54 nests were not used because 2 were destroyed by observers, 1 was incomplete and contained only 1 cowbird egg, and 51 were never observed to be active.

Estimates of annual productivity were calculated for the 2 most common nesting species, red-winged blackbirds and dickcissels, following Pinkowski (1979), in which annual productivity = (young fledged/successful nest)·(% nest success)·(nests/season). Because both species are polygynous, productivity values are given in young fledged/female/season. The number of nests/season was calculated by using the procedure reported by Austin (1977). For the red-winged blackbird, 8.5 days was calculated as the length for an unsuccessful nesting cycle, 18.3 days for an average nesting attempt, and a nesting season of 77-days (season length from Dinsmore et al. 1984). For the dickcissel, the length used for an unsuccessful nesting cycle was 10.0 days, for an average nesting attempt 27.4 days, and 77-days of nesting season (season length from Zimmerman 1982). Periods between failure or a successful nesting attempt and renesting for red-winged blackbirds were taken from Case and Hewitt (1963) and Frankhauser (1964). Because dickcissels are single-brooded (Zimmerman 1982), the period of time after a successful nest was considered the remainder of the breeding season. For the purposes of this estimate, we used the most conservative value by calculating this period from the first possible successful nest. The period between a nest failure and renesting for dickcissels was acquired from L. D. Igl (Dept. of Animal Ecology, Iowa State Univ., pers. commun). Daily mortality rates and percent nest success are in Table 1.

Vegetation Measurements

A stratified random sampling design was used to measure vegetation in waterways. One strip, 15 m wide, was delineated in the cropfield on each side of the waterway, and the waterway constituted a third strip. The strips were divided into segments 100 m long, and 1 sample site was located randomly within each segment. At least 5 samples were taken in each waterway. If the waterway had fewer than 5 segments, more than 1 sample was taken in each segment.

Four variables were measured at each waterway: plant residue cover, and vegetation height, density and composition. Two variables were also measured in the crop fields: crop residue cover and crop height. Crop residue cover was sampled in the crop field strips in April by using the bead string technique (Sloneker and Moldenhauer 1977). A 10-ft (3.1-m) long string with beads (marks) at 1-ft (15.3-cm) intervals was placed diagonal to the crop rows, and the number of beads that touched residue was recorded (Basore et al. 1986). Height of the field crops and height and density of the herbaceous vegetation in waterways were recorded twice a month. Vegetation density was measured with a density board (Gysel and Lyon 1980), 15 cm wide and 180 cm tall, and graduated at 10-cm intervals. At each sampling point, the board was viewed from the 4 cardinal directions at a distance of 3 m and a height of 1 m. The proportion of each interval obscured by vegetation was categorized as 0-20, 21-40, 41-60, 61-80, or 81-100% and recorded as 1-5, respectively. Density was calculated by averaging the measurements from the 4 cardinal directions at each interval and then summing over all intervals (Basore et al. 1986). In June, the peak nesting period (Best 1986), the composition of herbaceous vegetation in the waterways was determined by estimating the percent canopy coverage of plant species within a 1-m^2 quadrat. Individual coverages within each quadrat were estimated on a non-overlapping basis; thus total coverage summed to 100%. Only species with coverages of 5% or more were recorded. Herbaceous vegetation composition also was characterized by growth form (i.e., grasses, forbs, and shrubs). Coverage of plant residue and bare ground also were estimated within the quadrats. Because trees were generally restricted to fencerows adjoining waterways and were found growing in only 1 waterway sampled, they were not included as a growth form.

Statistical Analysis

The type of habitat adjoining waterways and the distance of a nest in the waterway from the adjoining end were evaluated for their influence on nest densities and success by using the General Linear Models (GLM) procedure (SAS Inst. Inc. 1985). Distance of a nest in the waterway from the adjoining end was determined by grouping the nests located within each of the 100 m segments delineated along the length of the waterway. If any of these tests were significant, the Duncan's multiple range test was used to determine which groups differed. When comparing means from only 2 groups of observations, student's t-tests were used except for comparisons of daily survival rates. Also, when variances were unequal, Satterthwaite's approximation was used to compute the "effective degrees of freedom" (Steel and Torrie 1980:106). Other tests used are described in the Results and Discussion. Statistical significance was set at $P \leq 0.05$.

RESULTS AND DISCUSSION

Habitat Characteristics

Vegetation characteristics in grassed waterways differed temporally between 1987 and 1988, primarily because of drought in 1988. Vegetation differences are detailed in Section I, but will only be briefly described here. The mean height and density of herbaceous vegetation in waterways was not significantly different between 1987 and 1988. We compared herbaceous vegetation only in unmowed waterways because vegetation height in mowed waterways was determined largely by mowing practices. Mean unmowed vegetation height in 1987 was 102 cm and in 1988, 75 cm. Vegetation densities in 1987 and 1988 were 46 and 35, respectively.

Grass was the most common vegetation growth form in the waterways (1987: 66% canopy coverage, 1988: 60%), being at least 3 times more abundant than forbs (1987-1988: 20%), the second most common growth form. Typically, waterways are planted to grass mixes, and any forbs present are usually invading weeds; however, waterways are sometimes planted with a legume in the grass mixture for the nitrogen-fixing benefits of the legume. Shrubs were scarce in the waterways (1987: 1% canopy coverage, 1988: 0%). The percent coverage of grass, forbs, and shrubs did not differ significantly between years ($\underline{P} > 0.30$). In contrast, residue in waterways increased from 1987 to 1988 (1987: 1% canopy coverage, 1988: 16%, $\underline{t} = 4.92$, 19 df, $\underline{P} > 0.01$), which we attributed to the drought drying out some of the grass, which was then categorized as residue.

Nine grass species were recorded in waterways. Smooth brome was the most abundant species (1987: 34% canopy coverage, 1988: 36%); orchard grass (Dactylis glomerata), reed canary grass (Phalaris arundinacea), and giant foxtail (Setaria faberii)were the next most common grass species. Twenty-six forb species were found in our waterways; alfalfa (Medicago sativa) was the most abundant, followed by sweet clover (Melilotus spp.), alsike (Trifolium hybridum), common ragweed (Ambrosia artemisiifolia), and giant ragweed (Ambrosia trifida).

Composition and Density of Nesting Species

Of the 10 bird species that nested in the waterways (Table 1), red-winged blackbird and dickcissel nests were the most common. In addition, a pair of American goldfinches (Carduelis tristis) began constructing a nest in 1988 but abandoned the attempt before completion. Nest densities (Table 2) of only 2 species approached significance (grasshopper sparrow: 1987: $\bar{x}$ = 4.4 nests/100 ha, 1988: $\bar{x}$ = 0, t =2.03, 11 df, P = 0.06) or were significantly different (western meadowlark: 1987: $\bar{x}$ = 3.8 nests/100 ha, 1988: $\bar{x}$ = 0, t = 2.57, 11 df, P = 0.03) between the 2 years of the study, thus, the 2 years were combined.

One hundred and seventy-one nests were found, resulting in a computed total nest density of over 1,200 nests/100 ha (Table 2). This is considerably higher than the 400 nests/100 ha reported by Basore et al. (1986) for strip cover in agricultural areas. This difference may be due in part to the more exhaustive searching technique used in our study. It also may demonstrate that waterways are a more attractive nesting habitat than other forms of strip cover (e.g., roadsides, herbaceous fencerows). The nest densities found in waterways also are much higher than those found in no-till and tilled crop fields (Basore et al. 1986).

Nest Success

The ring-necked pheasant had the highest nest success rate overall, but the dickcissel had the highest success rate among the nongame birds (Table 1). The field sparrow had the lowest nesting success, which appeared to be a common trend for all the nongame, ground-

Table 1. Nest success[a] of birds in grassed waterways in central Iowa cropfields from 15 May through 31 July 1987-1988

Species	Nesting cycle length (days)[b]	Days of exposure	Daily survival rate	Variance	Nest success (%)
Red-winged blackbird (Agelaius phoeniceus)	24	540	0.9019	0.0008	8.4
Dickcissel (Spiza americana)	24	227	0.9388	0.0002	22.0
Grasshopper sparrow (Ammodramus savannarum)	25	48	0.8958	0.0019	6.4
Common yellowthroat (Ceothlypis trichas)	25	26	0.8462	0.0050	1.5
Western meadowlark (Sturnella neglecta)	30	67	0.9104	0.0012	6.0
Vesper sparrow (Pooecetes gramineus)	24	36	0.8611	0.0033	2.8
Ring-necked pheasant (Phasianus colchicus)	30	58	0.9828	0.0003	59.3
Song sparrow (Melospiza melodia)	26	26	0.8846	0.0039	4.1
Field sparrow (Spizella pusilla)	23	13	0.7692	0.0137	0.2

[a]Nest success calculated by using the extended Mayfield method (Mayfield 1975, Johnson 1979).

[b]Nest cycle lengths taken from Besser et al. (1987) , Zimmerman (1982) , Smith (1963), Stewart (1953), Roseberry and Klimstra (1970), Rodenhouse and Best (1983), Bent (1963), Nice (1937), and Best (1978).

Table 2. Nest densities (nests/100 ha)[a] and fate (number) of nests[b] found in grassed waterways in central Iowa cropfields from 15 May through 31 July, 1987-88

Species	Nest densities	Active nests	Reason for failure						Success
			Abandoned	Predation	Mowing	Weather	Machinery	Cowbird parasitism[c]	
Red-winged blackbird	712	63	2	17	19	3	2	10	10
Dickcissel	280	27	0	12	1	1	1	5	7
Grasshopper sparrow	53	5	0	4	1	0	0	0	1
Common yellowthroat	53	3	0	1	0	1	0	1	0
Western meadowlark	45	6	0	1	2	2	0	1	0
Vesper sparrow	45	5	1	4	0	0	0	0	0
Ring-necked pheasant	38	3	0	1	0	0	0	0	2

Song sparrow	30	3	0	2	1	0	0	0	0
Field sparrow	23	3	1	2	0	0	0	0	0
Sedge wren	8	1	0	0	0	0	0	0	1
American goldfinch	8	0	--	--	--	--	--	--	--
Total	1,295	119	3	44	24	7	3	17	21

[a]Based on 1987-88 data combined, includes all nests located.

[b]Includes only those nests which were active (i.e., contained at least 1 host egg/young), whose cause and timing of failure could be determined, and which were not destroyed by the observer.

[c]Includes only nests which failed due cowbird parasitism (i.e., removal of all host eggs, induced desertion, starvation of host young).

nesting species. Red-winged blackbirds and dickcissels both commonly build their nests above the ground, and they had the highest success rates of the nongame species, although red-winged blackbird nest success was much lower than that of the dickcissels. This may be due, in part, to the increase of red-winged blackbirds nesting in the waterways in late July when mowing reached its peak (Fig. 1), thus destroying many of these late nests. Dickcissels moved into the waterways earlier in the breeding season and did not have as many late nests.

Mayfield nest success for red-winged blackbirds in grassed waterways was low (Table 1), but the daily survival rate was not significantly different from that reported for alfalfa fields in Iowa (0.8825, Frawley 1989) ($Z = 0.869$, $P > 0.05$). The apparent nest success reported for red-winged blackbirds for other Iowa upland habitats was 4% (Krapu 1978), and the percentage of eggs resulting in fledglings in wetland habitats and uplands in South Dakota ranged from 17 to 31% (Besser et al. 1987).

Daily survival rates for dickcissels in waterways (Table 1) were not significantly different from those calculated from Zimmerman (1982) for old field (0.9257) and prairie habitats (0.9403) ($Z = 0.944$ and 0.126, respectively, $P > 0.05$), but were higher than those reported for alfalfa fields (0.8125, Frawley 1989) ($Z = 3.76$, $P < 0.05$). This latter difference may be due to the greater number of exposure days (i.e., larger sample size) in our study or it could be because waterways were mowed less frequently than alfalfa fields.

Common yellowthroat nest success in waterways (Table 1) was low. Frawley (1989) only observed 1 common yellowthroat nest in alfalfa fields which was destroyed by mowing. Apparent success rate reported for common yellowthroats in wetlands was 83% (Stewart 1953). The daily nest survival rate for grasshopper sparrows in waterways (Table 1) was not significantly different from that in alfalfa fields (0.9268, Frawley 1989) or grasslands (0.9229, Johnson 1990) ($Z = 0.149$ and 0.584, respectively, $P > 0.05$).

Grasshopper sparrow nesting success in waterways was similar to the lower end of the 7-47% range of nesting success (Mayfield method) reported by Wray et al. (1982) for surface mines reclaimed to grassland.

The daily nest survival rate for vesper sparrows in waterways (Table 1) did not differ from the rate calculated for alfalfa fields (0.9318, Frawley 1989) ($\underline{Z} = 0.406$, $\underline{P} > 0.05$) or for cropfields (0.9190, Rodenhouse and Best [1983] as given by Frawley [1990]) ($\underline{Z} = 0.977$, $\underline{P} > 0.05$). Vesper sparrow nesting success, however, was very low when compared to the 15-22% Mayfield success rate reported for surface mines reclaimed to grassland (Wray et al. 1982).

The daily nest survival rate for western meadowlarks in waterways (Table 1) was not significantly different from alfalfa fields (0.8740, Frawley 1989) or grasslands (0.9364, Johnson 1990) ($\underline{Z} = 0.176$ and 0.717, respectively, $\underline{P} > 0.05$). Apparent nesting successes of 30-35% have been reported for western meadowlarks in grasslands (Lanyon 1957, Roseberry and Klimstra 1970).

Field sparrow nesting success was essentially 0 (Table 1), which is much lower than the 47% Mayfield nesting success rate reported by Wray et al. (1982) for surface mines reclaimed as grassland. Best (1978) reported an apparent nest success rate of 10% for field sparrows in grasslands and shrub-woodland habitats. Song sparrow (Melospiza melodia) nesting success in the waterways was also low (Table 1). Nice (1937) reported an apparent nest success of 42%.

Ring-necked pheasant success was the highest in our study, but the sample was small (Table 1). Apparent nest successes reported for ring-necked pheasant in cropfields, alfalfa, and roadsides have ranged from 15-29% (Soloman 1983, Basore et al. 1986, Warner et al. 1987). Ring-necked pheasant apparent nest success reported for hayfields in which mowing was delayed was 50-57% (Hartman and Fisher 1983).

Only 1 sedge wren (Cistothorus platensis) nest was found, which was successful. The apparent nest success of sedge wrens in an Iowa marsh was 68% (Crawford 1977).

Reasons for Nest Failure

The major cause of nest loss was predation (Table 2), which accounted for 57% of all losses (calculated following Heisey and Fuller [1985]). This is typical of many upland habitats (e.g., Wray et al. 1982, Picman 1988, Warner et al. 1987). In linear habitats like grassed waterways, greater predation may have been expected because predators have been found to actively search linear habitats (Allen 1941, Davison 1941). Shalaway (1985) and Snow and Mayer-Gross (1967), however, found that nest success was higher in fencerows and hedges, respectively, than in blocks of similar natural habitat. Increased predation may have also been expected due to the high nest densities of birds in the waterways. Zimmerman (1971, 1984) found that predation was not related to nest density, however, predation did increase with time over the breeding season. In our study the nesting success of some species, such as the dickcissel, was greater than or equal to the nest success in grasslands or hayfields. The overall predation rate in the waterways was similar to that observed for surface mines reclaimed to grassland, fallow fields, fencerows, and other strip cover in an agricultural area (Zimmerman 1971, Wray et al. 1982, Shalaway 1985, Basore et al. 1986). Therefore, the waterway characteristics of a linear configuration with high nest densities did not lead to greater nest predation.

The second most important cause for nest failure was mowing (16% of all losses). The proportion of nests lost to mowing in waterways was less than that reported for alfalfa fields, but the predation rate in waterways was higher (Frawley 1989). Fewer mowing losses occurred in waterways probably because not all waterways were mowed, whereas all alfalfa fields were mowed. Also, waterways were usually only mowed once/season, whereas alfalfa fields were generally mowed several times. If some alfalfa fields had not been mowed, there also may have been greater nest loss due to predation (e.g., see Hartman and Fisher 1983).

Other causes of nest failure included inclement weather, abandonment, and machinery, accounting for 9%, 8%, and 1% of all nest losses, respectively. Brown-headed cowbird parasitism accounted for another 9% of the nest losses. Twenty-seven percent of all nests in waterways were parasitized, but in many of these, adults were able to fledge their own young. This rate of cowbird parasitism is low compared to the rates reported for alfalfa fields (41-56%, Frawley 1989) and grasslands (60-85%, Zimmerman 1983). For birds nesting in fencerows, Shalaway (1985) did not observe any cowbird parasitism. Hergenrader (1962), however, reported the same rate of cowbird parasitism as we found in our study, 27%, for roadside nesting birds in Nebraska. Also, cowbird parasitism in waterways is within the range of 7-82% reported by Hill (1976) for cowbird parasitism of grassland birds in a prairie habitat.

Waterway Characteristics Influencing Nesting Density and Success

Nest density

Several aspects of the waterways were related significantly to nest densities. Nest density was positively correlated with vegetation height for red-winged blackbirds ($r = 0.67$, 22 df, $P < 0.01$), dickcissels ($r = 0.69$, $P < 0.01$), common yellowthroats ($r = 0.61$, $P < 0.01$), song sparrows ($r = 0.48$, $P = 0.02$), sedge wrens ($r = 0.53$, $P < 0.01$), and all species combined ($r = 0.81$, $P < 0.01$). Tall, dense vegetation is required by all of these species for nesting (Walkinshaw 1935, Nice 1937, Stewart 1953, Albers 1978, Buhnerkempe 1979, Kahl et al. 1985). An inverse relationship between vegetation height and nest density was found for grasshopper sparrows ($\underline{r} = -0.40$, $\underline{P} = 0.06$) and vesper sparrows ($\underline{r} = -0.43$, $\underline{P} = 0.04$). This also is consistent with documented nest habitat selection for these species (Whitmore 1979, 1981; Best and Rodenhouse 1984; Reed 1986). Nest densities in waterways were positively correlated with vegetation density for red-winged blackbirds ($\underline{r} = 0.77$, $\underline{P} < 0.01$), dickcissels ($\underline{r} = 0.55$, $\underline{P} < 0.01$), common yellowthroats ($\underline{r} = 0.41$, $\underline{P} = 0.05$), song sparrows ($\underline{r} = 0.46$, $\underline{P} = 0.03$), and all species combined ($\underline{r} = 0.81$, $\underline{P} < 0.01$). Nest densities were not significantly related to plant composition in waterways or to crop height.

Although nest densities were not related to plant species composition in waterways, over 3 times more nests were placed in or against forbs than in grass (Table 3). Sweet clover (see Table 3 for scientific names) was by far the most commonly used forb species for nesting by red-winged blackbirds and by all the species combined; curly dock was second in importance. Dickcissels also chose forbs predominantly as nest sites but did not seem to prefer any particular species. Grass was used more frequently as a nest substrate by dickcissels than by redwings. Of the forbs most commonly used as nest sites, only alfalfa is intentionally seeded in waterways. The remaining forbs species, with exception of curly dock, are problem weeds in crop fields (U.S.D.A. 1985).

The habitat adjoining waterways significantly influenced the nesting densities of dickcissels and field sparrows. Dickcissels nested more often in waterways associated with woodlots than in waterways adjoining any other habitat type (woodlots: $\underline{\bar{x}} = 13.9$ nests/100 ha, herbaceous fencerow: $\underline{\bar{x}} = 1.7$, pasture: $\underline{\bar{x}} = 0.8$, farmstead: $\underline{\bar{x}} = 0.6$, shrubby fencerow: $\underline{\bar{x}} = 0.4$, creek: $\underline{\bar{x}} = 0.4$, unconnected: $\underline{\bar{x}} = 0.0$; $\underline{F} = 2.76$; 6, 18 df; $\underline{P} = 0.04$). Field sparrow nests were found only in waterways adjoining shrubby fencerows (shrubby fencerows: $\underline{\bar{x}} = 0.9$ nests/100 ha; $\underline{F} = 2.74$; 6, 18 df; $\underline{P} = 0.04$).

Table 3. Number and percent of nests placed in various plant growth forms and in the most common[a] forb species in grassed waterways in Story and Marshall counties, Iowa from 15 May - 31 July 1987-88

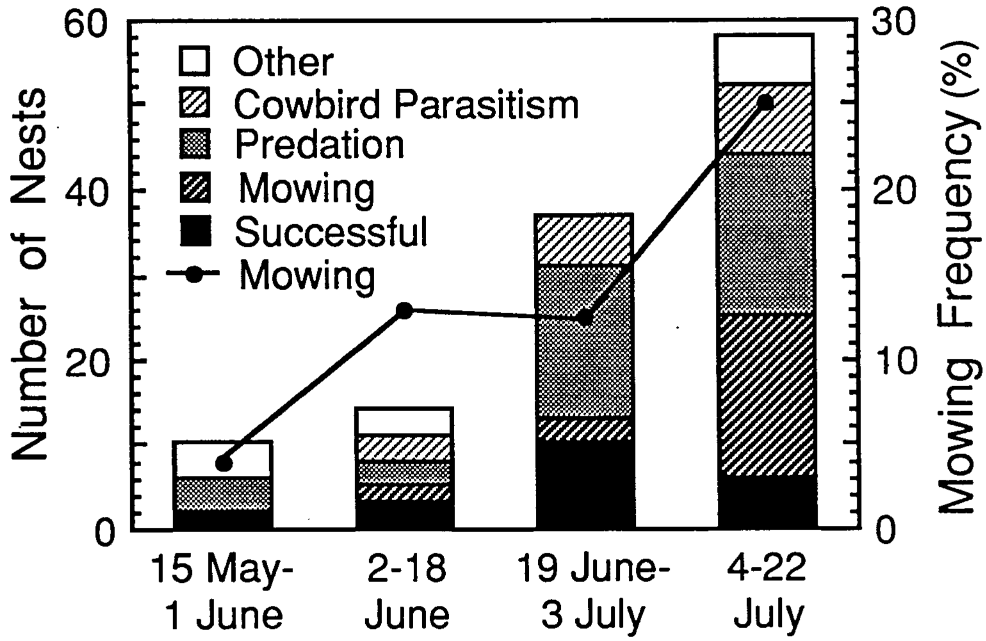
	Dickcissel		Red-winged blackbird		All species combined	
	n	%	n	%	n	%
Forbs	23	60.5	65	85.5	95	69.9
Sweet clover (Melilotus spp.)	4	17.4	35	53.8	39	41.1
Curly dock (Rumex crispus)	3	13.0	13	20.0	16	16.8
Giant ragweed (Ambrosia trifida)	1	4.3	7	10.0	10	10.5
Alfalfa (Medicago sativa)	3	13.0	1	1.5	8	8.4
Bull thistle (Cirsium vulgare)	4	17.4	0	0	4	4.2
Grasses	13	34.2	10	13.2	37	27.2
Shrubs	2	5.3	1	1.3	3	2.2
Residue	0	0	0	0	1	0.7

[a]Common = forb species in which at least 4 nests were located.

Mowing affected many species (Fig. 1), but only the nest densities of the red-winged blackbird were significantly different between unmowed ($\bar{x}$ = 75.8 nests/100 ha) and completely mowed ($\bar{x}$ = 3.8 nests/100 ha) waterways (t = 8.50, 2 df, P = 0.01). Mowing the previous year also affected nest densities during the current year for dickcissels and for all species combined. Dickcissels nested more commonly in waterways that had not been mowed the previous year ($\bar{x}$ = 121.2 nests/100 ha) than in those that had been mowed ($\bar{x}$ = 2.5 nests/100 ha) (t = 23.5, 2 df, P < 0.01). Also, the total nest density approached significance and was higher in waterways that had not been mowed the previous year ($\bar{x}$ = 227.3 nests/100 ha) compared to those that had been mowed ($\bar{x}$ = 35.4 nests/100 ha) (t = 3.41, 2 df, P = 0.07). Bird nesting preference for waterways not mowed the previous year could be related to 2 factors. First, waterways not mowed the previous year had taller and denser grass (see Section 1: Table 2), which would appeal to both dickcissels and common yellowthroats. Also, the lack of mowing may have increased nesting success in these waterways in previous year, causing more birds to return to the same site (i.e., greater site fidelity; Lanyon 1957, Best 1986).

Two other variables also were related to the nest densities of dickcissels and all species combined: waterway width and length. The shortest (150-304 m long) and widest (15-30 m wide) waterways had greater nesting densities of dickcissels and all species combined than the longest (609-900 m long) and narrowest (9-12 m wide) waterways. The nest densities for these width and length groups, however, were identical to the nest densities given above for waterways that were unmowed or mowed the previous year because certain width and length combinations were more likely to be mowed than others. All of the long and narrow waterways used in our study had been mowed the previous year, whereas the short and wide waterways were left unmowed. This trend is due to 2 factors which both relate to intensity of management by the landowner. First, long waterways were more likely to be mowed

Figure 1. The number of nests initiated and their outcome in relation to mowing frequency in grassed waterways in central Iowa cropfields during 4 time periods from 15 May through 22 July, 1987-88


Other
Cowbird Parasitism
Predation
Mowing
Successful
Mowing
Number of Nests
Mowing Frequency (%)
0
20
40
60
0
10
20
30
15 May-
1 June
2-18
June
19 June-
3 July
4-22
July

than short waterways, because the greater area covered by a long waterway has the potential for greater forage production and may harbor more weed pests. Second, because of the shorter grass, the edges of a mowed waterway are more likely to be cut into during plowing and tilling than the edges of an unmowed waterway. Over time, the width of the many mowed waterways decreases. Therefore, the difference in nest densities between waterway width and length classes for dickcissels and all species combined was more a function of mowing of the wateway. The width variable may still be influential to nest densities, but it is confounded with mowing. Width is the most important parameter influencing nest density in fencerows, another linear habitat (Shalaway 1985).

The distance from the habitat adjoining the waterway did not significantly influence nest placement. Also, crop type, crop residue, and crop row orientation (parallel vs. perpendicular to the waterway) had no significant affect on nest density.

Nest success

Several characteristics of the waterway vegetation influenced apparent nest success. The percentage of successful nests was positively correlated with grass height for red-winged blackbirds ($\underline{r} = 0.67$, 22 df, $\underline{P} < 0.01$), dickcissels ($\underline{r} = 0.43$, $\underline{P} = 0.04$), sedge wrens ($\underline{r} = 0.53$, $\underline{P} < 0.01$), and for all species combined ($\underline{r} = 0.68$, $\underline{P} < 0.01$). The percentage of successful nests also was related to grass density for red-winged blackbirds ($\underline{r} = 0.72$, $\underline{P} < 0.01$), dickcissels ($\underline{r} = 0.59$, $\underline{P} < 0.01$), and all species combined ($\underline{r} = 0.79$, $\underline{P} < 0.01$). One component of waterway vegetation composition also influenced nest success. The percentage of successful nests was positively correlated with the percent coverage of forbs for dickcissels ($\underline{r} = 0.65$, $\underline{P} < 0.01$) and approached significance for all species combined ($\underline{r} = 0.37$, $\underline{P} = 0.07$). Nest success was not significantly influenced by any of the other waterway characteristics measured.

Productivity

Annual productivity was estimated for the red-winged blackbird and dickcissel, as these were the only species with adequate sample sizes. The average number of host young fledged/successful nest for red-winged blackbirds was 2.9, and for dickcissels it was 3.6. Red-winged blackbirds were estimated to fledge 1.03 young/female/season in the waterways (see Methods), whereas dickcissels fledged 2.23. To sustain bird populations with an annual adult mortality of 50% (Lack 1968) and fledgling survival to the first breeding season of 12.5 to 25% (Ricklefs 1977, Pinkowski 1979), annual productivity must be from 4.0 to 8.0 fledglings per pair (Ricklefs 1977, Pinkowski 1979, Wray et al. 1982, Rodenhouse and Best 1983). The estimated annual productivity for red-wing blackbirds and dickcissels in grassed waterways is below the levels necessary for replacement. Unfortunately, waterways may function as ecological traps (Gates and Gysel 1978, Wiens and Rotenberry 1981, Best 1986), in that they provide attractive nesting cover for several bird species, resulting in relatively high nest densities, but offer little hope of net reproductive gain.

MANAGEMENT IMPLICATIONS

At least for red-winged blackbirds and dickcissels, waterways under current land-management practices function as ecological traps. Waterways are similar in structure to many grassland areas but evidently have causes of nest failure which result in production being below levels necessary to maintain populations of these species. Some of these sources of failure are controllable, as they involve human disturbance (i.e., mowing and machinery). Management practices that increase vegetation height and density, the relative coverage of forbs, and the width of the waterway also should increase nest densities and productivity.

Mowing was the second greatest cause of nest failure in the waterways and influenced nest densities in 2 ways. (1) Vegetation height and density were both affected by mowing, and this would influence those bird species that had nesting preferences either for waterways with tall and dense vegetation or for short and sparse plant cover. (2) The timing of mowing was of primary importance to birds nesting in the waterways, because the peak of mowing frequency coincided with the nesting peak in the waterways (Fig. 1). In the past, it has been recommended that mowing be deferred until after 15 July to minimize the adverse impact on nesting birds. Ordinarily this is an appropriate recommendation because the normal nesting peak for the species found in grassed waterways is mid-June (Best 1986, Frawley 1989). In the case of waterways, however, the nesting peak does not occur until mid-July, which may be because birds driven out of hayfields and other mowed areas renest in waterways. Despite this nesting peak in the waterways, the number of successful nests dropped dramatically because mowing frequency in the waterways also peaked at this time, consistent with existing recommendations. Consequently, waterways should not be mowed until late August or early September to allow for completion of these late nests.

The importance of unmowed waterways as habitat in mid to late summer is two-fold. At this time, similar habitats, such as hayfields and roadside ditches, have been mowed, thereby concentrating the birds in the remaining unmowed fragments of habitat provided by some waterways. This is supported by the shift in nesting peak from mid-June, which is normal for the species found in waterways, to mid-July, the actual nesting peak observed in the waterways. Also, in a recent study, banded male dickcissels were observed moving from alfalfa fields after mowing to unmowed waterways where they established new territories (L. D. Igl, Dept. of Animal Ecology, Iowa State Univ., pers. commun.) Secondly, uncut smooth brome has been shown to have the highest abundance of insects nutritious for young birds when compared with other grass types and alfalfa (Regenscheid et al. 1987). The predominant grass species in waterways was smooth brome; thus the increase in nest densities in waterways in mid to late summer may reflect the birds' preferences to select sites that provide an abundant food supply with which to feed their young. Warner and Joselyn (1986) found that ring-necked pheasant nesting success was higher in smooth brome roadsides than the combined nesting success in hayfields, pastures, small grains and other strip cover. Grass waterway habitats are comparable to roadsides, and, if left unmowed, ring-necked pheasant may also have similar nesting success in waterways.

To minimize the adverse affects on birds nesting in grassed waterways, waterways should be clipped high (15 to 30 cm) when they are mowed at the end of August or early September. Mowing shorter or any later than this would not allow sufficient regrowth of the vegetation to provide vegetative cover the following spring. Unless the waterway is being mowed for forage production, waterways should not be mowed annually because nest densities and successes were higher in waterways that were not mowed during our study and that had not been mowed the previous year. Annual mowing is not necessary to maintain grass vigor after the waterway is established, and weeds can be controlled by spot herbicide spraying or mowing (S. K. Barnhart, Extension Agronomist, Iowa State Univ., pers. commun.) which does has a negligible effect on bird use of waterways (see Section 1). It must be kept in mind, however, that mowing is sometimes necessary for forage production, and it does create a habitat that is more suitable for some species, such as vesper and grasshopper sparrows.

Another consideration in waterway management is the width of the waterway. Nest densities for some species were greatest in the widest waterways (15.0 to 30.0 m wide), which is consistent with the pattern of birds nesting in fencerows (Shalaway 1985). Consequently, it is important to establish and maintain waterways as wide as possible.

The majority of the nests located in the waterways were built in forbs (Table 3). Also, nesting success of some species was associated with the amount of forbs present in the waterway. Most forbs present in waterways are invading weeds. If these plants are not classified as noxious weeds and are not a seed source for problem weeds in the crop fields, they should be left for their benefits as nesting sites and/or food sources (Martin et al. 1951). Waterways are sometimes planted with a legume in the grass mixture for the nitrogen-fixing qualities of the legume; however, this practice is often discouraged because legumes are short-lived, leaving bare spots exposed to erosion (U.S.D.A. 1960). Cool season grasses, like smooth brome, need large amounts of nitrogen which can be provided efficiently and naturally by the addition of alfalfa to the grass mix (Barnhart 1986). In many cases, the benefits of nitrogen production by the legume may outweigh the cost of bare spots. Although alfalfa is short-lived, it can be interseeded as its production decreases. Alfalfa also provides more height than other legumes recommended for waterways, and it has been reported to be attractive nesting habitat for many grassland species when planted alone or in a mixture with smooth brome (Regenscheid et al. 1987, Warner et al. 1987, Frawley 1989). In this study, alfalfa was one of the most commonly used nesting substrates in the waterways (Table 3). Consequently, for many bird species, alfalfa would be an attractive addition to smooth brome plantings in grassed waterways.

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GENERAL SUMMARY

Forty-eight bird species were observed in waterways, compared with only 14 in the surrounding crop field. Red-winged blackbirds (Agelaius phoeniceus), dickcissels (Spiza americana), barn swallows (Hirundo rustica), western meadowlarks (Sturnella neglecta), brown-headed cowbirds (Molothrus ater), grasshopper sparrows (Ammodramus savannarum) and song sparrows (Melospiza melodia) were the most abundant bird species in the grassed waterways. Total bird abundance in the grassed waterways averaged 2,198 birds/100 ha compared to 682 birds/100 ha in crop fields.

Several waterway characteristics (e.g., grass and forb coverage, vegetation height and density) were significantly ($P \leq 0.05$) related to bird species richness and abundance in waterways. Bird use of waterways also was affected by the proximity of the waterways to diverted areas and by certain agricultural disturbances. In fields where crop rows ran perpendicular to the waterways, the increased farm vehicle disturbance in the waterways discouraged bird use of the waterways. Mowing, which drastically altered the structure of the habitat, greatly influenced bird use of the waterways; some bird species preferred mowed waterways, others preferred unmowed. Temporal patterns in bird abundance were attributed primarily to aspects of the waterways and surrounding cropland, such as crop and vegetation height, that changed over time. Bird abundance was greater in the segment of the waterways adjoining another habitat type then in segments farther from the edge habitat.

Ten species were observed nesting in the waterways; the red-winged blackbird (Agelius phoeniceus) and dickcissel (Spiza americana) were the most common. One hundred and seventy-one nests were found, with a nest density of 1,295 nests/100 ha. The extended Mayfield method was used to determined nest success rate, which was 8.4% for red-winged blackbirds and 22.0% for dickcissels. The 2 greatest causes of nest loss were predation, which accounted for 57% of all losses, and mowing accounting for 16% of all losses. Annual productivity in waterways was estimated at 1.03 young fledged/female/season for red-winged blackbirds, and 2.23 for dickcissels.

Waterways may be ecological traps for the nesting bird species under current management practices, but nest success might be increased by delaying mowing until late August or early September, or by not mowing annually and using spot herbicide spraying or spot mowing to control weeds. Delaying or eliminating mowing also is important because most (53%) of the species were at peak abundance in the waterways during 4 - 22 July, which is the currently recommended time for mowing.

In agricultural lands, where birds are highly concentrated in relatively small areas of remaining habitat, proper management of these areas becomes increasingly important. Proper management may entail some different strategies and recommendations for each of the fragments that make up the habitat mosaic in an agricultural ecosystem. In the case of grassed waterways, the traditional mowing dates set for birds in grassland habitats were highly detrimental. Therefore, each fragment of habitat in the agricutural ecosystem must be considered separately, no matter how small.

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